DRAFT

ATOFINA Chemicals, Inc.

Upland Remedial Investigation Report
Lots 3 & 4 and Tract A
ATOFINA Chemicals Facility
Portland, Oregon

05 February 2004

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LIST OF ACRONYMS

bgs	Below ground surface
BPA	Bonneville Power Administration
BTEX	Benzene, toluene, ethylbenzene, and xylenes
cfs	Cubic feet per second
COI	Constituent of interest
^{o}F	Degrees Fahrenheit
DNAPL	Dense non-aqueous phase liquid
DDD	1,1-dichloro-2,2- bis(p-chlorophenyl)ethane
DDE	1,1-dichloro-2,2- bis(p-chlorophenyl)ethylene
DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane, dichlorodiphenyltrichloroethane
ELF	Societe Nationale Elf Aquitaine
ERM	ERM-West, Inc.
ESA	Environmental Site Assessment
ESR	Environmental Summary Report
FS	Feasibility Study
FSP	Field Sampling Plan
GLISP	Guild's Lake Industrial Sanctuary Plan
HSA	Hollow-stem auger
IDR	Interim Data Report
IRM	Interim remedial measure
LOF	Locality of facility
MCB	Monochlorobenzene
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MIP	Membrane interface probe
MPR	Manufacturing process residue
MSB	Morrison Street Bridge

NGVD	National Geodetic Vertical Datum
OAR	Oregon Administrative Rule
ODEQ	Oregon Department of Environmental Quality
ORP	Oxidation/reduction potential
PAH	Polynuclear aromatic hydrocarbons
PBS	PBS Environmental
PCB	Polychlorinated biphenyls
pH	Acidity/alkalinity
PID	Photoionization detector
PRG	Preliminary remediation goal
PVC	Polyvinyl chloride
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RPAC	Rhone-Poulenc AG Company
SPLP	Synthetic Precipitation Leaching Procedure
SVOC	Semi-volatile organic compound
TCLP	Toxicity Characteristic Leaching Procedure
TLC	Thin-layer chromatography
TOC	Total Organic Carbon
TPH	Total petroleum hydrocarbon
U.S.	United States
USEPA	United States Environmental Protection Agency
VES	Vapor extraction system
VOC	Volatile organic compound
µg/L	Micrograms per liter

EXECUTIVE SUMMARY

A Remedial Investigation (RI) was performed at the ATOFINA Chemicals, Inc., (Atofina Chemicals) property in Portland, Oregon (the "facility" or "Site") between September 1998 and January 2004. In response to environmental impacts from manufacturing operations observed in prior investigations (Phase I and Phase II Site Characterization, CH2M Hill 1997) at the Site, ATOFINA Chemicals and the Oregon Department of Environmental Quality (ODEQ) entered into a Voluntary Agreement (ODEQ No. ECVC-WMCVC-NWR-97-14, dated 26 August 1998) to address impacts to soil and groundwater in the Acid Plant Area (area of former DDT manufacturing operations), and sediment in the Willamette River, adjacent to the Site (*Voluntary Agreement for Remedial Investigation/Feasibility Study*, ODEQ 1998). As part of the Voluntary Agreement, ATOFINA Chemicals prepared the *ATOFINA Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (the "Work Plan") (Exponent 1998). The Work Plan was approved by ODEQ in a letter dated 5 February 2003. The RI was conducted in accordance with the approved Work Plan.

RI activities conducted at the Site included both upland and in-water investigative work. Investigations conducted on the upland portion of the Site were completed in advance of in-water investigations. This RI Report incorporates results of the upland investigations and monitoring activities completed to date.

The initial focus of the upland portion of the RI was solely on the Acid Plant Area. Over time, as RI activities were carried out at the facility, the scope of the RI was expanded to examine environmental conditions site-wide. The expansion in scope was primarily the result of the Preliminary Assessment conducted by ATOFINA Chemicals. The *Preliminary Assessment for Elf Atochem North America, 6400 N.W. Front Avenue, Portland, Oregon* (Elf Atochem 1999), dated 31 August 1999, and subsequent review and comment by ODEQ, identified potential environmental impacts at the Chlorate Plant Area. Therefore, the focus of the RI was expanded to include both the Acid Plant and Chlorate Plant Areas.

In addition to the areal expansion of the RI, expansions in scope occurred to address additional data gaps identified as data were obtained, validated, and reviewed. Changes in scope were documented in correspondence between ATOFINA Chemicals and ODEQ in accordance with the Work Plan, which states: "Mutual decisions that represent a significant modification or change in scope will be documented in the work plan or under separate correspondence at Elf Atochem's [ATOFINA Chemical's] or ODEQ's option."

The Site is located at 6400 N.W. Front Avenue in Portland, Oregon, along the west bank of the Willamette River, at approximately river mile 7.5 in the Guild's Lake Industrial Sanctuary (formerly the Northwest Portland Industrial Sanctuary), zoned and designated "IH" for heavy industrial use. The Site occupies approximately 55 acres and is generally flat with surface elevations of approximately 25 to 38 feet National Geodetic Vertical Datum (NGVD) 1929. Approximately two-thirds of the plant was developed with buildings, paved roads, rail spur access, and associated tanks and piping in support of manufacturing processes (referred to as Lots 3 and 4). Since 2001, the facility has been in the process of decommissioning and much of the facility infrastructure has been demolished and removed, concurrent with RI activities.

Over the course of the RI, 222 soil borings were advanced for characterization of lithology, determination of aquifer hydrogeologic properties, collection of soil and groundwater samples, and installation of monitoring wells. Surface soil samples were collected from 13 locations for characterization of shallow Site soils. Soil samples were analyzed for organochlorine pesticides, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), petroleum hydrocarbons, metals, and physical parameters.

Thirty-two groundwater monitoring wells were installed at the Site as part of the RI. Groundwater samples were collected from soil borings and from monitoring wells to characterize site groundwater. Thirty groundwater samples were collected from soil borings and 181 groundwater samples were collected from Site wells. Groundwater samples were analyzed for total and dissolved organochlorine pesticides, VOCs, SVOCs, petroleum hydrocarbons, metals, perchlorate, and other miscellaneous analytes.

Twelve storm water samples were collected over the course of the RI to evaluate storm water quality during storm events. Storm water samples were collected during four sampling events and were analyzed for total and/or dissolved organochlorine pesticides.

Early RI activities conducted in 1999 noted the presence of residual dense non-aqueous phase liquid (DNAPL) in soil in the shallow zone beneath the former manufacturing process residue (MPR) pond and in a thin zone downgradient of the Acid Plant Area. Therefore, a two-phased DNAPL investigation was conducted in the Acid Plant Area in early 2002. The objective of the DNAPL investigation was to assess the extent of residual chlorobenzene DNAPL in the shallow and intermediate zones and to provide a basis for evaluating remedial alternatives.

In November 2001, at the time of decommissioning of the facility, PBS Environmental (PBS) performed a Phase II Environmental Site Assessment (ESA) for the Bonneville Power Administration (BPA) at the Pennwalt Substation. The Pennwalt Substation is located along the western edge of the Site. The Pennwalt Substation supplied electricity to the facility. BPA owned up to 15 transformers and circuit breakers within the substation. Soil samples were collected inside and adjacent to the substation and were primarily analyzed for polychlorinated biphenyls (PCBs). Select samples were also analyzed for petroleum hydrocarbons, VOCs, polynuclear aromatic hydrocarbons (PAHs), lead, 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane, dichlorodiphenyltrichloroethane (DDT), and metabolites. As a result of the earliest soil sampling within the substation, a soil removal was conducted, resulting in the excavation of approximately 80 cubic yards of soil. Soil samples were collected in the after the soil removal to document existing PCB concentrations in soil.

Results of the investigation indicated the following regarding Site geology:

- The surficial geology at the Site is characterized by fill and alluvial deposits of the Willamette River;

- Fill materials occur from the surface to depths of approximately 25 feet below ground surface (bgs) and consist of brown clayey silt to silty sand with occasional wood, brick, metal piping, and asphalt;

- The native soil profile is generally characterized by laterally discontinuous, alternating layers of dark gray-brown sand with varying amounts of silt and thinner silt layers with varying amounts of fine sand;

- Underlying the deepest silt layer, at a depth of approximately 35 feet, is a sand layer with black sands on the northern end of Lots 3 and 4 and dark gray-brown sands toward the southern end of the plant; and

- Columbia River Basalt is observed below the fill and alluvium at the Site at depths of 49 to 55 feet bgs.

Groundwater occurs in four distinct groundwater zones in the shallow fill and alluvial deposits on the Site (shallow, intermediate, deep, and basalt groundwater zones). In general, the depth to groundwater increases from west to east across the Site. Groundwater depths of approximately 6 to 12 feet bgs have been observed in monitoring wells along the western edge of the Site, whereas depths of approximately 14 to 32 feet have been observed in monitoring wells located in the eastern portion of the Site, along the riverbank.

In general, the groundwater flow direction across the Site is toward the Willamette River. The shallow groundwater surface fluctuates seasonally, rising during periods of high rainfall and infiltration and decreasing during mid- to late summer and low rainfall periods. In the Acid Plant Area, the groundwater flow direction has been observed to vary from east to northeast. Groundwater flow direction in the Chlorate Plant Area is generally to the east-southeast.

Results of tidal influence monitoring conducted as part of the RI suggest that Willamette River fluctuations are propagated inland through the intermediate and deep groundwater zones, but do not significantly alter the groundwater flow system at the Site.

Constituents of interest (COIs) were identified as a result of laboratory analysis of soil and groundwater samples collected during the RI. The primary COIs identified in upland soil consist of:

- DDT and its metabolites, 1,1-dichloro-2,2- bis(p-chlorophenyl)ethane (DDD) and 1,1-dichloro-2,2- bis(p-chlorophenyl)ethylene (DDE);

- Chlorobenzene; and

- Hexavalent chromium.

The primary COIs identified in upland groundwater consist of:

- DDT and its metabolites, DDD and DDE;

- Chlorobenzene;

- Hexavalent chromium; and

- Perchlorate.

These primary COIs were observed at higher concentrations and frequencies in environmental samples than other COIs identified during the RI.

DDT was observed in soil samples at concentrations of up to 16,000 milligrams per kilogram (mg/kg) in the former MPR pond. In general, DDT concentrations are greatest in shallow soils (up to 1 to 2 feet bgs) and decrease with depth. Soil in the vicinity of the two borings in which the highest DDT concentrations were observed, and the majority of shallow soil containing elevated DDT concentrations, was removed during a soil removal interim remedial measure (IRM). Several of the sample locations where elevated DDT concentrations were detected are beneath existing concrete building foundation slabs.

DDT and its metabolites were detected in shallow- and intermediate-zone groundwater downgradient of the Acid Plant Area. DDT is not typically observed in groundwater at concentrations greater than 1 micrograms per liter (µg/L). However, due to cosolvency with chlorobenzene, DDT has been observed in groundwater at concentrations up to 450 µg/L at the Site. The highest concentrations of DDT in groundwater were observed slightly upgradient of the highest concentrations of chlorobenzene. DDT was not observed in intermediate-zone groundwater in the Acid Plant Area during the two most recent sampling events (April 2002 and June 2003). Historically, DDT has been observed in deep- and basalt-zone groundwater at concentrations up to 0.43 and 0.022 µg/L, respectively. These concentrations are approximately three and four orders of magnitude less than the DDT concentrations observed in shallow-zone groundwater. DDT was not detected in the groundwater sample collected in June 2003 from the deep-zone monitoring well above the detection limit of 0.08 µg/L.

The RI has bounded groundwater affected by DDT in the shallow and intermediate groundwater zones upgradient and downgradient (Willamette River) of the Acid Plant Area. Additionally, the RI has bounded the northern and southern (cross-gradient) extents of DDT impacts in shallow-zone groundwater, as well as the northern and southern extents of DDT impacts in intermediate-zone groundwater.

Chlorobenzene was observed locally at low concentrations in shallow soil (zero to 3 feet bgs) in the Acid Plant Area. Concentrations of chlorobenzene up to 0.021 mg/kg were observed. Chlorobenzene was also observed in soil deeper than 3 feet bgs, over a slightly larger area than in shallow soil. Concentrations up to 8,800 mg/kg were detected in soil sampling borings, IRM borings, and vapor extraction system (VES) borings in the vicinity of the former monochlorobenzene recovery unit area. The highest chlorobenzene concentrations and a majority of the chlorobenzene mass were observed just above the silt layer situated at approximately 7.5 to 8 feet bgs. Although some chlorobenzene-impacted soil was removed during the IRM, chlorobenzene-impacted soil remains on site in the Acid Plant Area at depths up to 14 feet bgs.

Chlorobenzene was detected in shallow- and intermediate-zone groundwater, primarily downgradient of the Acid Plant Area. The maximum observed chlorobenzene concentrations were comparable for these two groundwater zones (260,000 and 140,000 µg/L); however, the lateral extent of chlorobenzene impact is greater in the shallow zone. Chlorobenzene was also detected in the deep- and basalt-zone monitoring wells. Chlorobenzene concentrations in the deep zone (10.6 µg/L) were approximately two to three orders of magnitude less than concentrations in the shallow zone; concentrations in the basalt zone (0.69 mg/L) were approximately four to five orders of magnitude less than concentrations in the shallow zone. Since chlorobenzene is present as residual DNAPL, these results suggest that the lower-permeability silt layers separating the groundwater zones have impeded significant downward transport of chlorobenzene.

This investigation has bounded groundwater affected by chlorobenzene upgradient and downgradient of the Acid Plant Area. The southern extent of chlorobenzene in the shallow zone and the northern extent of chlorobenzene in the intermediate zone have been well defined. However, further investigation is required to define northern extent of chlorobenzene in the shallow zone and the southern extent of chlorobenzene in the intermediate zone. A work plan for further investigation of the southern extent of chlorobenzene in the intermediate zone was submitted on 5 December 2003 and was approved by ODEQ on 15 January 2004. These investigations will be performed prior to conducting the Baseline Risk Assessment.

Residual DNAPL (chlorobenzene) was observed in the shallow and intermediate groundwater zones downgradient of the Acid Plant Area. A two-phased DNAPL investigation was carried out to further characterize the nature and extent of the observed DNAPL. The investigation concluded that residual DNAPL is generally confined to the lower portion of the shallow zone (i.e., within approximately 6 feet of the silt layer defining the bottom of the shallow zone), with the exception of one detection of residual DNAPL at intermediate-zone elevations below the former MPR pond. The investigation also concluded that the DNAPL is distributed as ganglia, and thus is not readily mobile in the subsurface. The DNAPL is a likely on-going source of dissolved chlorobenzene in groundwater.

Concentrations of chromium were observed in soil in the Chlorate Plant Area, at concentrations up to 180 mg/kg from zero to 4 feet bgs, and up to 1,600 mg/kg from 4 feet to approximately 32 feet bgs. The highest concentrations of chromium in soil are found in the immediate vicinity of the Chlorate Cell Room. Chromium concentrations decrease to typical background soil concentrations (i.e., 42 mg/kg; ODEQ 2002a) within approximately 250 feet of the Chlorate Cell Room.

Chromium and hexavalent chromium were detected in shallow- and intermediate-zone groundwater in the vicinity of the Chlorate Plant Area. Chromium was detected in a shallow-zone grab sample at a concentration of 110 mg/L (estimated value). A shallow-zone monitoring well was installed adjacent to the boring from which this sample was collected. The groundwater sample collected from this well contained chromium at a concentration of 0.601 mg/L, approximately two orders of magnitude lower than the concentration measured in the sample collected from the direct-push boring. This result suggests that the concentration of chromium in the groundwater sample collected from the direct-push boring may have been erroneously high. The highest chromium concentration detected in shallow-zone groundwater during the most recent groundwater sampling event was 9.79 mg/L. Chromium was also detected upgradient of the Chlorate Plant Area at a concentration of 0.00117 mg/L (June 2003). Chromium was detected in intermediate-zone groundwater at concentrations up to 1.15 mg/L during the most recent groundwater sampling event. The RI has adequately defined the extent of chromium impacts in groundwater for the purposes of performing a risk assessment and feasibility study (FS).

The RI identified perchlorate in shallow- and intermediate-zone groundwater. Concentrations up to 290 and 200 mg/L were observed in the shallow and intermediate groundwater zones, respectively. Perchlorate impacts in shallow-zone groundwater are more laterally extensive than those in the intermediate zone. The RI has bounded perchlorate in shallow-zone groundwater to the west (upgradient) and east (downgradient, Willamette River). Perchlorate was detected at a very low concentration in a shallow-zone monitoring well on the southern edge of the Site (0.110 mg/L). Additionally, perchlorate was detected in the northernmost monitoring well sampled for perchlorate (1.4 mg/L). Sampling of the northernmost shallow-zone well (MWA-5) will be performed prior to the performance of the risk assessment. For the purposes of performing a risk assessment and FS, the RI has adequately defined the extent of perchlorate impacts in the shallow and intermediate zones.

Chloride was observed in groundwater during all sampling events. Chloride is a naturally occurring ion in groundwater. However, elevated chloride concentrations were observed on the downgradient side of the former Salt Pads, where salt was stockpiled and where salt brine was produced for use in manufacturing. Concentrations up to 164,000 and 61,100 mg/L, respectively, were observed in the shallow and intermediate groundwater zones. The elevated chloride concentrations are limited to the area near the eastern edge of the former Salt Pads.

Total DDT and its metabolites were detected in storm water at low µg/L concentrations, which suggests that some pesticide-containing particulate material was present in the storm water samples. Significant reductions in total DDT and metabolite concentrations in storm water were observed after the Phase I soil removal IRM was completed; total DDT concentrations were approximately half of what had been previously observed, and DDT metabolite concentrations were approximately an order of magnitude less than previously observed levels.

The low concentrations of DDT and metabolites detected in storm water samples suggest that storm water runoff from the Site is not a significant source of DDT to Willamette River sediments.

All COIs identified in this RI will be evaluated in the Baseline Risk Assessment for the Site. In addition to the COIs, source areas, potential transport pathways, and potential receptors have been identified for application in the Baseline Risk Assessment.

Concurrent with implementation of the RI, interim remedial work was conducted at the ATOFINA Chemicals facility. Remedial work has included the following:

- Performance of two-phase soil removal IRM to mitigate potential environmental impacts from elevated DDT concentrations in soil;

- Installation and operation of a soil VES to reduce chlorobenzene concentrations in soil; and

- Performance of three remediation pilot studies and a bench-scale study to evaluate the effectiveness of potential remedial technologies.

Approximately 4,700 tons of DDT- and chlorobenzene-impacted soil were removed from the Acid Plant Area through implementation of the soil removal IRM. Additionally, capping of surface soil through installation of temporary surface cover and paving was conducted.

The three remedial pilot studies have been carried out at the facility evaluated remedial technologies to address the following:

- Elevated chlorobenzene concentrations in groundwater in the Acid Plant Area (In-Situ Sodium Persulfate Pilot Study Work Plan, [ERM 2001d]);

- The presence of DNAPL in the Acid Plant Area (DNAPL Pilot Study Work Plan, [ERM 2003c]); and

- Chromium in groundwater downgradient of the Chlorate Cell Room

In addition to the pilot studies carried out at the facility, a bench-scale study has been initiated to evaluate the effectiveness of in-situ anaerobic bioremediation to treat perchlorate in groundwater at the Site (*Scope of Work for Bench-Scale Testing of In-Situ Bioremediation to Treat Perchlorate in Groundwater at the ATOFINA Chemicals, Inc. Facility in Portland, Oregon*, [ATOFINA 2003b]).

A land and beneficial water use determination in the locality of facility (LOF) was conducted as part of the RI. For the purposes of the upland investigation and this report, the LOF is assumed to be the ATOFINA Chemicals facility and the riverbank to the mean high Willamette River water level. The future land use in the LOF will be industrial. The beneficial use for groundwater in the LOF is surface water recharge to the Willamette River.

The remedial investigation conducted at the ATOFINA Chemicals facility in Portland, Oregon, has adequately defined the nature and extent of COIs in upland soil and groundwater and provides sufficient data for conducting the Baseline Risk Assessment and FS.

1.0 INTRODUCTION

The ATOFINA Chemicals, Inc. (ATOFINA Chemicals) property in Portland, Oregon (the "facility" or "Site") is a former chemical manufacturing facility. The plant began operations at its current location in 1941 as a sodium chlorate plant. For the most part, the plant manufactured chlorine, sodium hydroxide, hydrogen, hydrochloric acid, and sodium chlorate. Other products and processes were added and discontinued over time. The insecticide 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane or dichlorodiphenyltrichloroethane (DDT) was manufactured at the plant between 1947 and 1954. The plant is no longer operating as a manufacturing facility and is currently undergoing decommissioning and demolition.

In June 1995, Elf Atochem requested a meeting with the Oregon Department of Environmental Quality (ODEQ) to discuss the DDT investigations and to submit an "Intent to Participate Form" for the ODEQ Voluntary Cleanup Program. In 1998, ATOFINA Chemicals entered into a Voluntary Agreement (ODEQ No. ECVC-WMCVC-NWR-97-14, dated 26 August 1998) with the ODEQ to address impacts to soil and groundwater in the Acid Plant Area and sediment in the Willamette River adjacent to the Site (*Voluntary Agreement for Remedial Investigation/Feasibility Study*, ODEQ 1998a). The Acid Plant Area has historically contained the majority of chemical manufacturing and processing activities (Elf Atochem 1999). As part of the Voluntary Agreement, ATOFINA Chemicals prepared the *ATOFINA Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (the "Work Plan") (Exponent 1998). The Work Plan was approved by ODEQ in a letter dated 5 February 2003. The remedial investigation (RI) was conducted between September 1998 and January 2004 in accordance with the Work Plan to supplement existing site data. The RI was conducted in accordance with Oregon Administrative Rules (OAR) 340-122-080 and the Voluntary Agreement.

1.1 PURPOSE OF REPORT

This RI Report presents a comprehensive summary of the RI scope, methodology, and results of activities performed to address the objectives outlined in the Work Plan and supplemental scope modifications. Results of RI activities performed between September 1998 and June 1999 were reported in the *Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report* (Exponent 1999). The Interim Data Report (IDR) identified data gaps and included recommendations for additional investigative work. This report presents the results of RI activities conducted to date, including the investigative work reported in the IDR.

The overall objectives of the RI were to:

- Evaluate Site physical characteristics, including surface features and hydrogeology;
- Identify constituents of interest (COIs) related to former manufacturing activities at the facility;
- Delineate the nature and extent of COIs in soil, groundwater, and sediment;
- Evaluate ongoing or future COI migration pathways and receptors based on the physical features and processes identified at the facility;
- Summarize site information to provide for evaluation of potential risks to human health or ecological receptors associated with COIs at the facility; and
- Provide a basis for conducting the Feasibility Study (FS).

The initial focus of the upland portion of the RI was solely on the Acid Plant Area. Over time, as RI activities were carried out at the facility, the scope of the RI was expanded to examine environmental conditions site-wide. The expansion in scope was primarily the result of the Preliminary Assessment conducted by ATOFINA Chemicals. The *Preliminary Assessment for Elf Atochem North America, 6400 N.W. Front Avenue, Portland, Oregon*, dated 31 August 1999 (Elf Atochem 1999), and subsequent review and comment by ODEQ, identified potential environmental impacts at the Chlorate Plant Area. Therefore, the focus of the RI was expanded to include both the Acid Plant and Chlorate Plant Areas.

The ATOFINA Chemicals property is divided into four lots and one tract along the Willamette River bank. Manufacturing processes took place on the southern two lots at the Site (Lots 3 and 4) with the northern portion of the Site (Lots 1 and 2) left relatively undeveloped. To expedite closure for the northern, undeveloped portion of the Site, ATOFINA Chemicals prepared the *Environmental Summary Report, Lots 1 and 2* (ERM-West, Inc. [ERM] 2003a). The purpose of the Environmental Summary Report (ESR) was to support a "No Further Action" decision by ODEQ for Lots 1 and 2. The ESR provided a focused Remedial Investigation/Feasibility Study (RI/FS) summary in support of an ODEQ Staff Report and a No Further Action decision based on available data. The focus of this report is on RI activities carried out on Lots 3 and 4, which include the Acid Plant and Chlorate Plant Areas.

In addition to the areal expansion of the RI, expansions in scope occurred to address additional data gaps identified as data were obtained, validated, and reviewed. Changes in scope were documented in correspondence between ATOFINA Chemicals and ODEQ in accordance with the Work Plan, which states: "Mutual decisions that represent a significant modification or change in scope will be documented in the work plan or under separate correspondence at Elf Atochem's [ATOFINA Chemical's] or ODEQ's option." As such, this RI Report does not include a detailed discussion of each scope change (i.e., rationale). However, the results of all investigations conducted as part of the original scope and all scope modifications are discussed in this report.

Field investigations of soil, groundwater, sediment, and storm water were conducted to meet the objectives outlined above. RI activities conducted at the Site included both upland and in-water investigative work. Investigations conducted on the upland portion of the Site were completed in advance of in-water investigations. This RI Report incorporates results of the upland investigations and monitoring activities completed to date. A separate in-water report, the *Phase II Stage 1 and 2 In-River Groundwater and Sediment Investigation Report*, summarizing in-water investigation activities was submitted to ODEQ on 9 December 2003 (Exponent 2003).

1.2 SITE BACKGROUND

This section provides a brief description of the Site, information on the historical operations at the Site, and a general description of the physical setting of the Site. In this report, map directions given in the text are in reference to the layout of plant facilities rather than geographic directions, for consistency with usage at the Site as defined in the Work Plan. For example, north (i.e., plant north) in the text and figures is equivalent to geographic northwest.

1.2.1 *Site Description*

The Site is located at 6400 N.W. Front Avenue in Portland, Oregon, along the west bank of the Willamette River, at approximately river mile 7.5 in the Guild's Lake Industrial Sanctuary (formerly the Northwest Portland Industrial Sanctuary), zoned and designated "IH" for heavy industrial use (Figure 1-1). The Site is bordered on the east by the Willamette River, on the south by CertainTeed Roofing Products Company, and on the north and west by Front Avenue (Figure 1-2). The Site occupies approximately 55 acres and is generally flat with surface elevations of approximately 25 to 38 feet National Geodetic Vertical Datum (NGVD) 1929. The Site is surrounded by steel security fencing. Security personnel attend the main gate 24 hours a day.

Approximately two-thirds of the plant was developed with buildings, paved roads, rail spur access and associated tanks and piping in support of manufacturing processes (Lots 3 and 4, Figure 1-3). The plant is currently in the process of decommissioning and much of the facility infrastructure has been demolished and removed, concurrent with RI activities. Demolition is being carried out in three phases. Phase I consisted of removal of steel structures and tanks. Phase II involved demolition of site buildings from Lot 3 and the northern portion of Lot 4. The Phase II demolition was performed in accordance with the ODEQ-approved *Phase II Demolition Work Plan*, dated 1 May 2003 and approved by ODEQ on 9 May 2003 (ATOFINA Chemicals 2003a). The Phase III demolition is scheduled to take place in the summer of 2004 and will be performed in accordance with an approved work plan.

1.2.2 *Site Ownership History*

The facility started operations in 1941 to meet wartime needs for chlorate production in the western United States (U.S.). It was built by Pennsylvania Salt Manufacturing, which later became known as Pennwalt Corporation (Pennwalt). In 1989, Societe Nationale Elf Aquitaine (ELF), an international manufacturer and distributor of petroleum, health care, and chemical products, purchased Pennwalt. Pennwalt's operations were combined with those of two other companies to form Elf Atochem North

America, Inc., in 1990. In 2000, ELF merged with TOTALFINA to form TOTALFINA ELF and Elf Atochem became ATOFINA Chemicals, Inc.

1.2.3 Site Operational History

Various chemicals have been historically produced at the facility since 1941, including sodium chlorate, potassium chlorate, chlorine, sodium hydroxide, DDT, sodium orthosilicate, sodium hydroxide, magnesium chloride hexahydrate, ammonia, ammonium perchlorate, and hydrochloric acid. Most recently, the facility was an operating chloro-alkali plant until 2001 when the entire facility was shut down due to escalating electricity costs.

The initial RI activities focused on potential environmental concerns in the former DDT manufacturing area in the Acid Plant Area. During the RI, the Chlorate Plant Area was identified as an area of potential environmental concern. RI activities reported herein focused primarily on these two areas (Figure 1-4). The following paragraphs provide a description of the operational histories of these two areas.

1.2.3.1 Acid Plant Area Operational History

The pesticide DDT was manufactured in the Acid Plant Area between 1947 and 1954. The raw materials used to manufacture DDT included:

- Chloral (trichloroacetaldehyde);
- Chlorobenzene (also known as monochlorobenzene [MCB]); and
- Oleum-104 percent (fuming sulfuric acid).

DDT was manufactured inside the former DDT process building (Figure 1-5). Manufacturing process residues were discharged to a floor drain in the DDT process building during the initial startup. From 1948 to 1950, process residues were discharged directly to a manufacturing process residue (MPR) pond located northeast of the building. From 1950 until DDT manufacturing ceased completely in 1954, the manufacturing process residue was piped to an MCB recovery system and then into the shallow MPR pond. In approximately 1951 or 1952, a trench was reportedly constructed and extended north about 200 feet from the northeastern corner of the former MPR pond (Figure 1-5).

From 1950 until the termination of the process, wastes were conveyed through piping to an MCB recovery system. The system reportedly was located immediately west of the former MPR pond. The recovery system consisted of a steam stripper, in which chlorobenzene was removed from the waste and returned to the process. The entire system was located on a curbed concrete slab. Wastes from the system reportedly were drained periodically to the former MPR pond.

The area designated as the Acid Plant Area was used for all materials-handling operations associated with the manufacturing and handling of DDT and associated wastes.

The raw materials chlorobenzene and oleum were purchased from outside sources and stored in aboveground tanks located immediately adjacent to the eastern side of the process building. Chloral was formulated from the chlorination of ethanol on site and stored in an aboveground tank located inside the process building on a concrete floor. Chemical reactions to form DDT occurred inside the process building, where portable metal pans several feet square were filled with hot DDT. After the DDT cooled, the material in the pans was broken with a jackhammer to form large fragments of crystalline material. The crystalline DDT was temporarily stored on an asphalt slab located in the Acid Plant Area.

The DDT at the storage slab was transferred to the southwestern corner of the No. 2 Warehouse for milling and grinding inside the warehouse. Dry-processed DDT was loaded into bags and transported from the plant by railcar. The railcar loading area was located on the northern side of the No. 2 Warehouse. A small amount of material was dissolved in diesel fuel and loaded into trucks and possibly railcars as a solution. The aboveground dissolving tanks were located immediately adjacent to the western side of the DDT process building. This building was extended westward after DDT operations ceased.

In 1958, after DDT manufacturing shut down, ammonium perchlorate operations were conducted in the former DDT process building. Sodium perchlorate was converted to ammonium perchlorate by using ammonium chloride. This material was sold as a solid propellant for guided missiles. The operations were shut down in approximately 1962. Some ammonium perchlorate handling took place in the No. 3 Warehouse, adjacent to the Acid Plant Area to the southeast.

1.2.3.2 *Chlorate Plant Area Operational History*

Sodium chlorate manufacturing started in 1941 in its current location (Figure 1-4). Chlorate was produced by electrolysis of a sodium chloride solution. Sodium bichromate was added to the process as a corrosion inhibitor and to improve the electrical efficiency of the process. The bichromate was received in a dry form. Historically, the material came to the plant in sealed bags and was stored inside the chlorate department. The bags were opened inside the chlorate cell room and the contents were dissolved in tanks with water. The solution was fed into the circulating liquor in the chlorate cell room.

Beginning in the early 1990s, sodium bichromate was received in 30-gallon metal drums. The drums were also stored inside the chlorate department. The bichromate material was dissolved in the 30-gallon drums and was siphoned into tanks for incorporation into the circulating liquor.

Historically, the sodium chlorate solution product contained sodium bichromate. Chlorate solutions were shipped either by truck or barge. Truck loading occurred on the southern side of the Chlorate Plant Area. Barge loading of chlorate solutions occurred at the No. 2 Dock. After the completion of a chlorate plant modernization project in 1990, very little sodium bichromate was contained in chlorate products. The sodium bichromate was separated from the chlorate solution and returned to the circulating liquor.

Potassium chlorate manufacturing also started in the Sodium Chlorate Area in 1941. This operation terminated in approximately 1978. Production operations were similar to sodium chlorate operation with the exception that potassium chloride was used as the source of salt rather than sodium chloride.

In 1952, production of a sodium chlorate-based cotton defoliant material was initiated. Magnesium chloride was brought into the plant and hydrated to form magnesium chloride hexahydrate. This activity was conducted in the former No. 1 Warehouse. The magnesium chloride hexahydrate was brought to the northern end of the sodium chlorate process area where it was ground and mixed with sodium chlorate. The blended material was bagged and sold. This operation was conducted for approximately 10 years.

1.2.3.3 *Operational History of Salt Pads*

The ATOFINA Chemicals plant historically received salt (sodium chloride, NaCl) by ship. The salt was transferred onto asphalt-lined Salt Pads in the southeastern corner of the Site (Figure 1-2). The salt was dissolved in water while on the Salt Pads to produce brine for plant manufacturing operations. Salt was the primary raw material used at the Site throughout its operational history (1941 to 2001).

1.2.4 *Previous Investigations*

Investigations of the Acid Plant Area have been conducted since 1994. In 1994, ATOFINA Chemicals conducted a Phase 1 soil and groundwater investigation to establish the presence or absence of COIs in soil in the Acid Plant Area and the former DDT MPR pond and to evaluate the quality of groundwater in the vicinity of the MPR pond. In 1996 and 1997, a Phase 2 investigation was conducted to further investigate the nature and extent of COIs in the soils and shallow groundwater in the Acid Plant Area.

A summary discussion of findings from investigations conducted prior to September 1998 is contained in the Work Plan. Pertinent results from previous investigations are incorporated in this RI Report.

1.3 *REPORT ORGANIZATION*

This RI Report is organized into eight sections:

- Section 1 provides general introductory information;
- Section 2 discusses the RI field program;
- Section 3 describes the physical characteristics of the study area;
- Section 4 discusses the results of the remedial investigation sampling;
- Section 5 presents the extent of contamination and conceptual site model;
- Section 6 summarizes interim remedial actions;
- Section 7 discusses land and beneficial water use;

- Section 8 discusses hot spots;
- Section 9 presents the summary of findings and conclusions; and
- Section 10 contains a list of references.

Boring logs for all borings conducted for the RI are included in Appendix A of this report.

2.0 FIELD PROGRAM

This section presents a summary of the RI field program. The RI field program was conducted over a period of approximately 5 years, from late 1998 to late 2003. To meet the objectives of the Work Plan, the RI field program included the collection and analysis of:

- Soil samples;
- Groundwater samples;
- Storm water samples;
- Soil physical testing;
- Aquifer testing; and
- Tidal influence monitoring.

As discussed in Section 1.0, the field program was modified to address newly identified potential environmental concerns. Thus, the scope of the RI field program was expanded beyond the original scope of the Work Plan. Modifications to the Work Plan scope or Field Sampling Plan (FSP) (Appendix A of the Work Plan) methods or procedures are discussed in the applicable paragraphs. Rationale for and approval of modifications to the initial RI scope have been documented in correspondence between ATOFINA Chemicals and ODEQ and are not discussed herein.

2.1 SOIL INVESTIGATION

Soil sampling was conducted for the purposes of evaluating soil physical properties, field screening, and delineating COIs in soil. Soil samples were collected from the following borings and/or locations:

- Soil sampling borings (77 borings);
- Interim Remedial Measure (IRM) borings (81 borings);
- Vapor Extraction System borings (32 borings);
- Monitoring well borings (32 borings);

- Surface soil sample locations (7 locations); and
- Riverbank soil sample locations (6 locations).

The following paragraphs describe the soil investigation tasks.

2.1.1 *Soil Sampling Borings*

During field activities, 77 soil sampling borings were advanced for collection of soil and groundwater grab samples. These borings were advanced using either hand-auger, direct-push (Geoprobe®), or hollow-stem auger (HSA) drilling methods. Depth of these borings ranged from 2 to 54 feet below ground surface (bgs). A summary of soil sampling borings is provided in Table 2-1. This summary includes the boring number, date of completion, boring depth, drilling method, and indicates the analyses conducted on soil samples collected from each boring. Boring logs for soil sampling borings are provided in Appendix A. Soil sampling boring locations are shown on Figure 2-1.

Soil samples were collected from discrete depth intervals. Most samples were field-screened after collection. Screening methods included thin-layer chromatography (TLC), Sudan IV® hydrophobic dye, photoionization detector (PID), or visual inspection, as described in the FSP. Soil samples were submitted to the laboratory for archiving and analysis. Select samples from the borings were analyzed for constituents as listed in Table 2-1 (e.g., volatile organic compounds [VOCs], organochlorine pesticides, etc.). Following completion, the boring was abandoned with bentonite grout as described in the FSP.

The Work Plan originally called for eight soil borings in the Acid Plant Area (four Acid Plant Perimeter borings, three Unpaved Area borings, and one former DDT MPR pond boring). The 77 soil sampling borings advanced in Lots 3 and 4 over the 5-year period of the RI represent a significant expansion of the original Work Plan scope. Additionally, in several cases, soil borings were advanced to greater depths than initially stated in the Work Plan. Procedures described in the FSP were followed for all soil boring field activities to ensure data quality. Notice was given to and approval was received from ODEQ for the modifications to the RI scope.

2.1.2 *Interim Remedial Measure Borings*

During execution of Work Plan activities, an IRM was implemented to remove soil containing DDT near the former MPR pond in the Acid Plant Area. The IRM was carried out in two phases in accordance with the *Interim Remedial Measures Work Plan* (Exponent 2000) *and Phase II Soil Interim Remedial Measure Workplan* (ERM 2001a). The IRM is discussed in Section 6.0.

Eighty-one borings were advanced to delineate the extent of soil containing DDT to support the IRM. Approximately 42 of the 81 borings were completed in soils that were subsequently removed during the IRM. The IRM borings were advanced to depths from 5 to 13 feet bgs using direct-push (Geoprobe®) drilling methods. A summary of IRM soil borings is provided in Table 2-2. Boring logs for the IRM borings are provided in Appendix A. IRM boring locations are shown on Figure 2-2.

Soil samples were collected from discrete depth intervals and were field-screened after collection. Screening methods included TLC, Sudan IV® hydrophobic dye, PID, or visual inspection, as described in the FSP. Soil samples were submitted to the laboratory for archiving and analyses as indicated in Table 2-2. Following completion of each boring, the boring was abandoned with bentonite grout as described in the FSP.

The original RI scope did not include the IRM borings. These borings were completed in accordance with the *Interim Remedial Measures Work Plan* (Exponent 2000). The IRM borings were completed in accordance with procedures for the soil sampling borings described in the FSP.

2.1.3 *Vapor Extraction System Borings*

In December 2000, a soil vapor extraction system (VES) was installed in the former MCB Recovery Unit Area in accordance with the *Workplan for Full-Scale Vapor Extraction System*, dated 26 September 2000. The VES was installed to reduce chlorobenzene concentrations in soil below the Resource Conservation and Recovery Act (RCRA) regulated threshold level. The VES is discussed in Section 6.0.

As part of the pilot test and full-scale implementation of the soil VES, 32 VES borings were completed, which included eight hand-auger borings and 24 vapor monitoring point borings. These borings were advanced using both hand-auger and direct-push (Geoprobe®) methods to depths of 1 to 16 feet bgs. A summary of VES borings is provided in Table 2-3. Boring logs for VES borings are provided in Appendix A. No boring logs were prepared for the hand-augered VES borings AP-1 through AP-8. The VES boring locations are shown on Figure 2-3.

Soil samples were collected from discrete depth intervals and were field-screened by TLC, Sudan IV® hydrophobic dye, PID, or visual inspection. Soil samples were submitted to the laboratory for archiving and analysis of VOCs as indicated in Table 2-3. Following completion of each boring, the boring was either abandoned with bentonite grout or completed as a monitoring point with a polyvinyl chloride (PVC) well riser and screen for use during pilot testing and full-scale VES implementation.

2.1.4 *Monitoring Well Borings*

Soil sampling was conducted in soil borings advanced for the installation of groundwater monitoring wells. A total of 32 borings were completed for the installation of monitoring wells, which included 18 shallow zone, 12 intermediate zone, one deep-zone, and one basalt-zone monitoring well borings. These groundwater/lithologic zones are discussed in Section 3.0. The total number of borings includes the two borings advanced to replace abandoned monitoring wells MWA-6 and MWA-15. Monitoring well borings were advanced using HSA or cable tool drilling methods to depths ranging from approximately 26 to 70 feet bgs. Where monitoring well borings were advanced through low-permeability silt zones, the borings were cased off to prevent direct vertical hydraulic connection between water-bearing zones. A summary of monitoring well borings is provided in Table 2-4. Boring logs for monitoring well borings are provided in Appendix A. Monitoring well locations are shown on Figure 2-4.

Soil samples from monitoring well borings were visually inspected and logged for lithology in accordance with procedures in the FSP. In addition, soil samples were collected from discrete depth intervals and many were field-screened after collection. Screening methods applied included TLC, Sudan IV® hydrophobic dye, PID, or visual inspection, as described in the FSP. Soil samples were submitted to the laboratory for archiving and/or analyses as indicated in Table 2-4. Each monitoring well boring was completed as a monitoring well, as described in Section 2.2.

The number of monitoring well borings exceeded the initial eight monitoring well borings scoped in the Work Plan. In addition, monitoring well borings were advanced beyond the depths initially scoped in the Work Plan. The supplemental monitoring well boring work was approved by ODEQ through correspondence, as described in Section 1.0.

2.1.5 Soil Physical Testing

Select soil samples were collected from borings for analysis of soil physical properties in accordance with the Work Plan. Samples were tested for hydraulic conductivity, bulk density, liquid limit, plastic limit, percent moisture, and grain size. Tables 2-1 through 2-4 indicate which borings were sampled for soil physical testing.

2.1.6 Surface Soil Sampling

Surface soil samples were collected at seven locations in the vicinity of the Acid Plant Area and south of No. 1 Dock, adjacent to the Willamette River, to characterize surface soil. Surface soil sampling locations are shown on Figure 2-5. Surface soil samples were collected from depths of zero to 4 inches bgs at locations S-2 through S-8 and were analyzed for organochlorine pesticides by U.S. Environmental Protection Agency (USEPA) Method 8081A. Collection of surface soil samples was not included in the Work Plan and was conducted as an additional RI task. Collection and analysis of surface soil samples was conducted in accordance with soil sampling methods described in the FSP.

2.1.7 Riverbank Soil Sampling

Soil samples were collected from the riverbank along the Willamette River. Samples were collected on the riverbank slope face between the top of slope and the mean high water elevation of the Willamette River. Samples were collected from six locations along the riverbank. Three samples were collected within approximately 5 feet of the top of slope and three samples were collected directly downslope of those locations, approximately 5 feet above the mean high water river water elevation. Riverbank soil sampling locations are shown on Figure 2-6. Riverbank soil samples were analyzed for organochlorine pesticides by USEPA Method 8081A, semi-volatile organic compounds (SVOCs) by USEPA Method 8270C, and total cadmium, chromium, lead, and zinc by USEPA

Method 6010B. Collection of the riverbank samples was not included in the Work Plan. Collection and analysis of riverbank soil samples was conducted in accordance with soil sampling methods described in the FSP.

2.2 *GROUNDWATER INVESTIGATION*

The RI field program groundwater investigation included collection and laboratory analysis of groundwater grab samples, monitoring well installation, measurement of groundwater levels, evaluation of aquifer hydraulic properties, and collection and laboratory analysis of monitoring well groundwater samples.

2.2.1 *Soil Boring Groundwater Grab Sampling*

Groundwater grab samples were collected from 30 of the 77 soil sampling borings. Table 2-1 indicates the borings from which groundwater grab samples were collected. Table 2-5 provides a summary of analyses and analytical methods for groundwater grab samples. Collection of groundwater grab samples was not included in the Work Plan. Collection and analysis of grab groundwater samples was conducted using methods described in the FSP.

2.2.2 *Monitoring Well Installation and Development*

Thirty-two new monitoring wells were installed in four separate groundwater zones. Groundwater monitoring wells were installed in accordance with OAR, Water Resources Department, Chapter 690, Division 240; ODEQ Groundwater Monitoring Well Drilling, Construction and Decommissioning Guidelines; and the Work Plan and its supplemental approved work plan addenda. Wells were installed using HSA or cable tool drilling methods. Monitoring well locations are shown on Figure 2-4. A summary of monitoring well installation data and as-built construction specifications is provided in Table 2-6. Boring and well construction logs are provided as Appendix A.

2.2.2.1 *Shallow-Zone Monitoring Well Installation*

Eighteen new shallow-zone monitoring wells were installed to depths between approximately 29 and 38 feet bgs. The shallow-zone monitoring wells were installed and screened at elevations similar to those of the existing monitoring wells MWA-1 through MWA-4, which were installed as part of early investigative work at the Site, prior to the Voluntary Agreement and development of the Work Plan . The shallow-zone monitoring wells were constructed with stainless steel wire-wrapped screens and stainless steel casing to above the groundwater surface and were completed to the ground surface with PVC casing. In general, the shallow-zone monitoring wells are screened in alluvial sands, with the bottom of the screen placed at or near the interface with an underlying silt horizon.

Stainless steel centralizers were utilized to center the well screen and casing. Washed silica sand (#10-20) was used as a filter pack around each well screen and was generally placed to 2 feet above the top of the screen interval.

2.2.2.2 *Intermediate-Zone Monitoring Well Installation*

Eleven intermediate-zone monitoring wells were installed to depths ranging from approximately 35 to 59 feet bgs. Nine of the eleven intermediate-zone wells were placed within the intermediate alluvial sands below one or more confining silt or equivalent fine-grained soil horizons. Although they were designated as intermediate-zone wells, monitoring wells MWA-28i and MWA-31i were screened within the deep groundwater zone silts and clays, above the bedrock basalt. Lithology of the Site is described in Section 3.0.

The new intermediate-zone monitoring wells were constructed with stainless steel wire-wrapped screens and stainless steel casing to above the groundwater surface, and were completed to the ground surface with PVC casing.

Stainless steel centralizers were utilized to center the well screen and casing. Washed silica sand (#10-20) was used as a filter pack around each well screen and was generally placed to 1 to 2 feet above the top of the screen interval.

2.2.2.3 *Deep-Zone Monitoring Well Installation*

One deep-zone monitoring well (MWA-13d) was installed to a depth of 53 feet bgs. The deep-zone monitoring well was screened at the bottom of the deep alluvial silts and sands at the interface with the underlying basalt horizon. The new deep-zone monitoring well was constructed with a stainless steel wire-wrapped screen and stainless steel casing to above the groundwater surface and was completed to the ground surface with PVC casing. Deep-zone monitoring well construction procedures were similar to those for the shallow- and intermediate-zone monitoring wells, described above.

2.2.2.4 *Basalt-Zone Monitoring Well Installation*

One groundwater monitoring well (MWA-21b) was completed in the basalt zone underlying the deep zone. This boring was advanced to a depth of approximately 69 feet bgs. The basalt-zone monitoring well was constructed with a stainless steel wire-wrapped screen and stainless steel casing to above the groundwater surface, and was completed to the ground surface with PVC casing. The construction procedures for the basalt-zone monitoring well were similar to those for the other new monitoring wells, described above.

2.2.2.5 *Monitoring Well Development*

New monitoring wells were developed within 24 hours to 1 week after installation by surging and over-pumping using a positive-displacement pump. In addition, three of the four existing wells (MWA-2, MWA-3, and MWA–4) were redeveloped by over-pumping with the positive displacement pump, in an effort to remove silt that had accumulated since the original installation and development.

Well development procedures were conducted as described in the FSP. A minimum of approximately 20 well casing volumes was removed from the new monitoring wells during development. This is more than originally proposed in the FSP. The additional development was required due to the presence of abundant suspended fine-grained materials in the development water, in addition to the required removal of drilling fluids (i.e., water) added during boring advancement in the intermediate zone and deeper wells.

2.2.2.6 *Abandonment of Monitoring Wells*

Three monitoring wells were abandoned during the RI. Monitoring well MWA-1 was abandoned on 26 August 1999. Monitoring well MWA-6 was abandoned on 4 August 1999 and was replaced by MWA-6r on 5 August 1999. Monitoring well MWA-15 was abandoned on 18 September 2000 and was replaced by MWA-15r on 2 July 2001. Wells were abandoned by backfilling with bentonite to the ground surface.

2.2.3 *Groundwater Elevation Monitoring*

Groundwater levels were measured in facility monitoring wells periodically, prior to groundwater quality sampling. Water levels were measured with an electronic water level indicator, in accordance with the procedures described in the FSP.

2.2.4 *Tidal Influence Monitoring*

Groundwater levels in shallow-, intermediate-, and deep-zone groundwater monitoring wells were monitored to measure the effects of tidal fluctuations and river stage in the Willamette River on groundwater levels. The data were used to gain an understanding of groundwater gradients and flow directions beneath the Site. Diurnal tidal fluctuations were monitored during a typical mid-winter river stage on 3 to 8 February 1999. During the tidal monitoring event, pressure transducers were installed in five shallow-zone wells (MWA-2, MWA-3, MWA-4, MWA-5, and MWA-7), six intermediate-zone wells (MWA-8i, MWA-9i, MWA-10i, MWA-11i, MWA-12i, and MWA-14i), one deep-zone well (MWA-13d), and a river stage stilling well mounted on Dock #1. The pressure transducers were mounted at a fixed depth so that changes in groundwater levels could be accurately recorded. The data loggers were synchronized and automatically recorded the water level in each well at 15-minute intervals for a period of approximately 120 hours. Water levels were manually collected at the beginning, middle, and end of the monitoring period to verify the automatically recorded data. Data were analyzed using a mathematical averaging method presented by Serfes (1991). The mathematically averaged data were used to generate a groundwater elevation map and to evaluate representative groundwater gradients and flow directions for the shallow and intermediate zones.

2.2.5 *Aquifer Testing*

Aquifer testing was conducted on shallow-, intermediate-, and deep-zone monitoring wells (five shallow zone, six intermediate zone, and one deep zone), in accordance with the FSP. Aquifer testing was conducted to evaluate hydraulic conductivity and to provide information on the variation in hydraulic conductivity laterally and vertically in the shallow, intermediate, and deep groundwater zones.

The aquifer tests consisted of the insertion and withdrawal of a fixed-volume solid tube or "slug," such that the rate of water level recovery in the well could be monitored before and after slug insertion and removal. Water level data for each slug test were collected using a pressure transducer and data logger that automatically recorded changes in water levels during the test. The slug test data were evaluated using the Bouwer and Rice (1986) analytical method. Aquifer test data and plots are located in the *Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report* (Exponent 1999). As a modification to the Work Plan scope, slug tests were conducted on two more monitoring wells than originally planned (one additional intermediate-zone and the deep-zone well).

2.2.6 *Monitoring Well Groundwater Sampling*

Groundwater sampling activities were carried out as part of the RI. Groundwater samples were collected as both grab samples during soil boring activities (as indicated in the boring summary Tables 2-1 through 2-4) and from groundwater monitoring wells.

Prior to monitoring well sampling, each well was developed and allowed to stand for a minimum of 7 days prior to sample collection. The first groundwater sampling event was conducted from 25 to 29 January 1999 on the 14 monitoring wells that existed at the time (MWA-1 through MWA-14i). Initially, wells were sampled using a pneumatic bladder pump and samples were collected after a minimum of three well casing volumes had been purged from the well. In a letter to ODEQ dated 31 May 2001, ATOFINA Chemicals proposed the use of low-flow groundwater sampling procedures for the Site (ERM 2001b). Written approval of the low-flow procedure was provided by ODEQ on 6 June 2001. The description of the low-flow procedure is provided in the 31 May 2001 letter (ERM 2001b).

During purging of each monitoring well, field parameters (i.e., temperature, acidity/alkalinity [pH], oxidation/reduction potential (ORP), dissolved oxygen, specific conductance, and turbidity) were measured within a flow-through cell to verify that water quality had stabilized prior to sample collection. Groundwater samples were then collected directly from the pump discharge tubing. Groundwater samples were collected in sample containers with the proper preservative (if required) and were packed in a cooler with ice for transport to the analytical laboratory under chain of custody. Groundwater sampling methods are described in more detail in the Work Plan and the 31 May 2001 letter describing low-flow sampling procedures.

Groundwater samples were analyzed for some or all of the following:

- Total and dissolved organochlorine pesticides by USEPA Method 8081A;
- VOCs by USEPA Method 8260B;
- SVOCs or polynuclear aromatic hydrocarbons (PAHs) by USEPA Method 8270C or 8270SIM;
- Total petroleum hydrocarbon (TPH) diesel range by Washington Department of Ecology Method NWTPH-Dx;
- Metals (Calcium, chromium, hexavalent chromium, iron, magnesium, manganese, potassium, and sodium) by USEPA Method 6010B and 6020;
- Perchlorate by USEPA Method 314.0;
- Carbonate and bicarbonate alkalinity by USEPA Method 2320B and total alkalinity by USEPA Method 310.0;
- Ammonia as nitrogen by USEPA Method 350.1;
- Nitrate, nitrite, sulfate, and total chloride by USEPA Method 300.0, 353.2, or 354.1;
- Total organic carbon (TOC) by USEPA Methods 415.1 and 9060 Mod;
- Chloral hydrate by USEPA Method 551.1;
- p-chlorobenzenesulfonic acid; and
- Dissolved methane by USEPA Method RSK 175.

A summary matrix of groundwater sampling events indicating the date, well number, and suite of analyses for each sample is provided in Table 2-7.

During the most recent round of groundwater sampling, two wells installed as part of the In-Situ Sodium Persulfate Pilot Study were included in the suite of monitoring wells for sampling. These wells (NMP-3D and NMP-4D) were completed in the shallow groundwater zone in areas of high chlorobenzene concentrations in groundwater, approximately 50 feet downgradient from the former MPR pond. Monitoring wells NMP-3D and NMP-4D were installed using similar methods to those used for installation of RI monitoring wells. Well completion information for these wells is provided in Table 2-6. The locations of these wells are shown on Figure 2-4. Boring logs for these wells are provided in Appendix A. Discussion of the Persulfate Pilot Study is located in Section 6.3.

2.3 STORM WATER DRAIN SAMPLING

Storm water samples were collected from two storm drain systems that enter manholes within the Acid Plant Area. Sampling events were carried out on 22 January, 11 November, and 17 December 1999, and 27 March 2001.

The storm water samples were collected from each drain system at its point of entry to the manhole prior to mixing with non-contact cooling water discharge. Storm water samples were submitted to the laboratory for analysis of total and/or dissolved organochlorine pesticides by USEPA Method 8081A. The samples collected on 17 December 1999 were analyzed for total pesticides only. During storm water sample collection, field parameters (i.e., temperature, pH, specific conductance, ORP, dissolved oxygen, and turbidity) were measured in a separate aliquot of water.

The four storm water sampling events represent an expansion in scope over the two scheduled events in the Work Plan. Storm water sampling was conducted in accordance with the FSP.

2.4 *DENSE NON-AQUEOUS PHASE LIQUID INVESTIGATIONS*

Early RI activities conducted in 1999 noted the presence of residual dense non-aqueous phase liquid (DNAPL) in soil in the shallow zone beneath the former MPR pond and in a thin zone downgradient of the Acid Plant Area. The observed residual DNAPL was found primarily near the shallow zone/upper silt layer interface. The presence of elevated dissolved-phase chlorobenzene concentrations in MWA-15r (Section 4.0) suggested that residual DNAPL within the Acid Plant Area might be a continuing source of dissolved chlorobenzene in groundwater.

A two-phased DNAPL investigation was initiated in early 2002 in accordance with the *Work Plan for Dense Non-Aqueous Phase Liquid Investigation, Acid Plant Area, ATOFINA Facility, Portland, Oregon* (ERM 2002a). The objective of the DNAPL investigation was to assess the extent of residual chlorobenzene DNAPL in the shallow and intermediate zones and to provide a basis for evaluating remedial alternatives.

2.4.1 *Phase I DNAPL Investigation*

The Phase I field program utilized a combination of cone penetrometer testing, membrane interface probe (MIP) screening, and direct-push (Geoprobe®) groundwater sampling to characterize subsurface conditions. Detailed descriptions of the field methods and field program are presented in the *Work Plan for Dense Non-Aqueous Phase Liquid Investigation* and the *Residual Dense Non-Aqueous Phase Liquid Investigation (Phase I), Acid Plant Area, ATOFINA Facility, Portland, Oregon* report (ERM 2002b). The Phase I field program was carried out between 5 and 15 February 2002.

2.4.2 *Phase II DNAPL Investigation*

The Phase II field program was conducted to further characterize the nature and extent of residual chlorobenzene DNAPL in the shallow zone and to evaluate the presence and extent of residual DNAPL in the intermediate zone. Seven direct-push borings were advanced in the area of the former MPR pond. Three groundwater and three soil samples were collected for analysis of chlorobenzene and TOC, respectively. Detailed descriptions of the field methods and field program are presented in the *Workplan Addendum for Residual Dense Non-Aqueous Phase Liquid Investigation (Intermediate-Zone Sampling), Acid Plant Area* (ERM 2002c) and the *Phase II Residual Dense Non-Aqueous Phase Liquid Investigation (Intermediate-Zone Sampling), Acid Plant Area* report (ERM 2002d). The Phase II field program was carried out between 10 June and 3 July 2002.

2.5 *BONNEVILLE POWER ADMINISTRATION MAIN SUBSTATION SOIL SAMPLING*

In November 2001, PBS Environmental (PBS) performed a Phase II Environmental Site Assessment (ESA) for the Bonneville Power Administration (BPA) at the Pennwalt Substation. The Pennwalt Substation is located along the western edge of Lot 3 of the Site and is referred to as the BPA Main Substation on Figure 1-3. The Pennwalt Substation supplied electricity to the facility. At the time of the Phase II ESA, the substation contained up to 15 transformers and circuit breakers, all of which were known or assumed to contain polychlorinated biphenyls (PCBs). The Phase II ESA was conducted in accordance with the *Sampling and Analysis Plan, Phase II Environmental Site Assessment for Bonneville Power Administration, Pennwalt Substation, 6400 NW Front Avenue, Portland, Oregon* (PBS 2001). The purpose of the Phase II ESA was to “document the environmental condition of the facility at the time of decommissioning, evaluate cleanup requirements, and to collect sufficient information regarding the nature and extent of contamination to assist BPA in making informed business decisions.” (PBS 2002). The results of the Phase II ESA were reported in the *Phase Two Environmental Site Assessment for Bonneville Power Administration, Pennwalt Substation* report (PBS 2002).

Seventy-two soil samples were collected by PBS within the substation. Soil samples were collected around oil-containing equipment with foundations and beneath racks with suspended oil-containing equipment. Samples were also collected from other areas of concern, such as stained soil and disturbed ground surfaces. In general, samples were collected approximately 0.5 foot from each concrete pad and from zero to 0.5 foot bgs. Sixty-four of the 72 BPA Main Substation soil samples were analyzed for PCBs by USEPA Method 8082. Additionally, select soil samples were analyzed for the following:

- TPH (diesel- and heavy oil-range) by Method NWTPH-Dx;
- Chlorobenzene and 1,1,1-Trichloroethane (method unspecified);

- Benzene, toluene, ethylbenzene, and xylenes (BTEX) (method unspecified);
- PAHs (method unspecified);
- Lead (method unspecified); and
- DDT and 1,1-dichloro-2,2- bis(p-chlorophenyl)ethylene (DDE) (method unspecified).

In March 2002, eight additional soil samples were collected by BPA inside and outside the substation. Two of the samples were collected within surface water drainage swales north and south of the substation (one sample from each swale). The location of these eight additional samples is shown on Figure 2-7.

After BPA had removed electrical equipment (i.e., transformers and circuit breakers), ATOFINA Chemicals collected soil samples within the BPA substation (June 2002). Thirty-seven shallow surface soil samples were collected and were analyzed for diesel- and residual-range hydrocarbons by method NWTPHDx and PCBs by USEPA Method 8082. PCBs were detected in 12 of the 37 samples. Most PCB detections were at concentrations less than 1 milligram per kilogram (mg/kg) (8 of 12 detections). The highest PCB concentration detected was 8.5 mg/kg. Locations of these samples are shown on Figure 2-7.

As a result of the ATOFINA Chemicals sampling, BPA conducted a soil removal in the northwestern corner of the substation to a depth of approximately 4 feet. Approximately 80 cubic yards (in-place measurement) were ultimately removed from the substation. The final extent of the soil removal excavation is shown on Figure 2-7. BPA collected confirmation samples from the bottom and sidewalls of the completed excavation. Confirmation samples consisted of a composite of four samples from each side of the excavation at three depths (zero, 1.5 , and 3 feet bgs) and four samples from the bottom of the excavation for a total of 16 confirmation samples.

In addition to the 12 confirmation samples, BPA collected eight discrete surface soil samples in the area between the substation and Front Avenue. The discrete soil sample locations are shown on Figure 2-7.

Analytical results for soil samples collected in and around the BPA Main Substation are presented and discussed in Section 4.5.

Soil sampling conducted in and around the substation was conducted primarily by BPA. Therefore, sample collection, analytical, and data validation methods may have differed from the methods defined in the RI FSP.

2.6 FIELD SCREENING

During RI field activities, multiple soil samples were collected from the various types of borings completed. Most soil samples were selected for laboratory analysis by field screening by one of the following methods:

- PID for the detection of VOCs;
- Sudan IV® hydrophobic dye for the detection of residual DNAPL; and
- TLC for the detection of DDT.

In addition, groundwater samples collected during the field activities were field-screened using one or more of the above methods. A description of each method is provided in the FSP (Exponent 1998) and the Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report. Field screening was not conducted on soil and groundwater samples collected from the Chlorate Plant Area, where DDT and VOCs were not expected.

2.7 FIELD SURVEYING

Upon completion of monitoring well installation and development, a horizontal and vertical control survey was conducted on new and existing monitoring wells and other sample locations (i.e., borings, storm water sample locations) to establish coordinates and elevations of the sample locations. W&H Pacific, Inc., an Oregon-licensed surveyor, conducted the surveys. Reference elevations were established to the nearest 0.01 foot and are referenced to the City of Portland Datum. Horizontal coordinates were established to the nearest 0.1 foot and referenced to Oregon State Plane Coordinates. Survey data (i.e., ground surface elevation, top of casing elevation) for each of the site wells are reported in Table 2-6.

2.8 INVESTIGATION-DERIVED WASTE MANAGEMENT

Investigation-derived waste included soils, groundwater, decontamination fluids, and personal protective equipment generated during drilling, well installation, development, and sampling activities. Investigation-derived waste was placed in sealed, labeled 55-gallon drums. Based on soil and groundwater analytical results and drum composite sample analyses, the drum contents were profiled at the Site. The drums were transported to the Chemical Waste Management Subtitle C facility in Arlington, Oregon, for disposal. If the waste exceeded the criteria for hazardous waste by toxicity characteristic leaching procedure (TCLP) for chlorobenzene, the drums were transferred from the Arlington facility to a licensed hazardous waste incinerator.

2.9 QUALITY ASSURANCE DATA REVIEW

The laboratory analytical data for soil, groundwater, and storm water samples collected during the RI were subjected to rigorous independent quality assurance (QA) review. Environmental Standards, Inc. of Valley Forge, Pennsylvania, performed the QA reviews. The reviews were performed in accordance with the *National Functional Guidelines for Organic Data Review* (USEPA, October 1999); the *National Functional Guidelines for Inorganic Data Review* (USEPA, February 1994); the Quality Assurance Project Plan (Appendix B, the Work Plan); and Environmental Standards' professional judgment.

Data were examined to determine the usability of the analytical results and compliance relative to the method requirements specified in USEPA's *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition*. Data qualifiers and project-specific descriptors were applied to the analytical results as appropriate based on the criteria evaluated. Use of these data qualifiers and descriptors allows the qualitative and/or quantitative reliability of the analytical results to be assessed. Detailed descriptions of the data review procedures and results are contained in the Quality Assurance Project Plan (Appendix B of the RI/FS Work Plan, Exponent 1998) and in QA review reports submitted to ODEQ with previous data transmittals and progress reports.

After analytical data were reviewed, they were incorporated into an electronic database for storage, retrieval, data analysis, and reporting. The analytical data presented in this RI Report have undergone the review process summarized above.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section summarizes the physical characteristics of the Site, including climate, the site-specific geology, surface water hydrology, hydrogeology, and ecological resources.

3.1 CLIMATE

The climate in the Portland area is temperate with dry, moderately warm summers and wet, mild winters. January and February receive 40 to 50 percent of the annual precipitation, and the summer months receive 25 percent of the annual precipitation (National Oceanic and Atmospheric Administration and U.S. Department of Commerce 1974).

The average annual precipitation in Portland is 37.6 inches. The average lake evaporation is 24 to 26 inches annually (U.S. Department of Commerce 1968). The monthly average relative humidity ranges from 65 to 84 percent. Monthly average temperatures range from 41 degrees Fahrenheit (°F) in the winter to approximately 70 °F in the summer. Daily minimum temperatures in January average 32 °F; daily maximum temperatures in July average 79 °F. Winds are generally aligned with the Willamette River Valley.

3.2 SITE GEOLOGY AND SOILS

The surficial geology at the Site is characterized by fill and alluvial deposits of the Willamette River. Alluvial deposits are underlain by bedrock of the Columbia River Basalt Group. A discussion of regional geology is provided in the Work Plan.

3.2.1 Fill Material

Fill materials occur from the surface to depths of approximately 25 feet bgs and consist of brown clayey silt to silty sand with occasional wood, brick, concrete, metal piping, and asphalt. Historically, fill materials were used to extend the ground surface out into the Willamette River. Fill thickness ranges from a few feet in the former manufacturing area to approximately 25 feet along the riverbank.

The source of the fill is generally believed to be river dredge spoils and deposits from on- and off-site excavations. This was an accepted practice for near-shore areas of properties along the Portland Harbor. The City of Portland was reportedly allowed to dispose of used asphalt from roadways. The shallow, fine-grained soils are the result of dredged material from the Willamette River being placed on the upland portions of the Site. In some areas of the Site, this has resulted in an extension of the ground surface into the river by up to 150 to 200 feet. A cross section layout map and cross-section diagrams (Sections A-A′, B-B′, C-C′, and D-D′) are provided on Figures 3-1 through 3-5.

3.2.2 *Alluvial Deposits*

Based on boring logs completed for the RI (Appendix A), the native soil profile is generally characterized by laterally discontinuous, alternating layers of dark gray-brown sand with varying amounts of silt and thinner silt layers with varying amounts of fine sand. These sands and silts are massive to finely laminated and the contacts between the sand and silt can be gradational. In general, there are four alternating sand and silt layers; a sand layer occurs at the ground surface, underlain by a silt layer at approximately 8 feet bgs, which is underlain by additional sand and silt layers. The sand and silt layers are continuous over most of the Site. The lowest silt layer becomes less continuous in the southern portion of the Site adjacent to the Willamette River.

Underlying the deepest silt layer, at a depth of approximately 35 feet, is a sand layer with black sands on the northern end of Lots 3 and 4 and dark gray-brown sands toward the south. A deeper silt layer with some clay and fine sand is situated beneath the black and dark gray-brown sand and above the basalt bedrock. Physical properties of select samples of alluvial soils are reported in Table 3-1.

Regionally, the Troutdale Formation, composed of sandstone and conglomerate, is inferred to be present below the unconsolidated fill and alluvium and is likely to be laterally discontinuous throughout the area (Geraghty & Miller 1991). The presence of the Troutdale Formation beneath the Site has not been confirmed by this or previous investigations. The limited occurrence of the Troutdale Formation is probably attributable to erosion by the ancestral Willamette River.

3.2.3 *Bedrock*

Columbia River Basalt is inferred at a depth below the fill and alluvium throughout the area. Basalt was detected in three monitoring well borings conducted as part of the RI (MWA-13d, MWA-14i, and MWA-21b), at depths of 49 to 55 feet bgs. These borings are located downgradient (east) of the Acid Plant Area. Basalt was not observed in two borings, MWA-11i and MWA-12i, that were advanced to depths of 51 to 52 feet bgs, upgradient of the Acid Plant Area, or in borings MWA-28i and MWA-31i, advanced to depths of approximately 59 to 60 feet bgs, downgradient (east) of the Chlorate Plant Area. Regionally, the basalt surface dips to the east; however, a trough or basin has been identified in the upper basalt surface during other investigations near the facility (Geraghty & Miller 1991). This finding is supported by data from this investigation.

3.3 *SURFACE WATER HYDROLOGY*

The facility is located along the west bank of the Willamette River at approximately river mile 7.5. The daily mean Willamette River discharge in Portland ranges from 8,300 cubic feet per second (cfs) in summer (August) to 63,000 cfs in winter (December). The mean daily flow is 31,000 cfs for the period of 1972 to 1994. The confluence of the Willamette and Columbia Rivers is approximately 7.5 miles northwest of the Site. The Willamette River is not used as a drinking water source downstream of the Site.

The Willamette River is gauged at the Morrison Street Bridge (MSB) at river mile 12.8, approximately 5 miles upstream of the Site. The datum at the MSB is 1.55 feet NGVD (U.S. Army Corps of Engineers 1991). Thus, Willamette River stage data from the MSB are converted to NGVD by adding 1.55 feet.

The minimum monthly river stage along the Willamette River in the Portland Harbor area typically occurs during September and October. Maximum monthly stages usually occur in the winter (December through February) and in the spring (March through June), coincident with flood peaks on the Willamette and Columbia rivers (U.S. Army Corps of Engineers 1991). Two extreme daily stage levels were recorded on 9 February 1996, when the river stage reached more than 28 feet and on

2 February 1997 when the river stage reached nearly 23 feet. For water years 1973 to 1990, the minimum daily stage of 1.1 feet was recorded in November 1979 and the maximum daily stage of 23.8 feet was recorded in January 1974.

The Willamette River stage is influenced by upstream reservoir regulation on both the Willamette and Columbia rivers (up to the Bonneville Dam) and by tidal effects from the Pacific Ocean. Tidal effects are most pronounced, typically ranging from 2 to 3 feet in amplitude per tidal cycle, when the river stage is less than about 8 feet (MSB gauge). Tidal influences are more moderate (i.e., less than 2 feet in amplitude) between river stage elevations of 8 to 14 feet (MSB gauge). Above approximately 14 feet, tidal fluctuations are generally absent in the Portland Harbor. Tidal influences are most pronounced during the summer and fall when river flow and river stage are typically at their lowest (U.S. Army Corps of Engineers 1991).

The ground surface at the Site is generally flat. Site drainage is generally towards catch basins which contribute to four storm water outfalls, which discharge to the Willamette River.

3.4 SITE HYDROGEOLOGY

3.4.1 Groundwater Zones

Groundwater occurs in the shallow fill and alluvial deposits on the Site. Groundwater depths of approximately 6 to 12 feet bgs have been observed in monitoring wells along the western edge of the Site (monitoring wells MWA-7, MWA-12i, and MWA-23). Depths of approximately 14 to 32 feet have been observed in monitoring wells located in the eastern portion of the Site, along the riverbank. Groundwater depths in the Acid Plant and Chlorate Plant Areas are greater than approximately 20 feet bgs. A summary of groundwater elevation data is provided in Table 3-2.

Groundwater occurs in four distinct groundwater zones beneath the Site. Unconfined groundwater has been observed in the shallow groundwater zone at depths of approximately 6 to 32 feet bgs in the uppermost fill and sand alluvium. In general, the depth to groundwater increases from west to east across the Site (from Front Avenue toward the Willamette River). The saturated thickness of the shallow groundwater zone is defined as the depth from the potentiometric surface to the upper surface of the silt layer situated just above the black and dark gray-brown sand and ranges from approximately 15 to 25 feet near Front Avenue to approximately 2 to 15 feet near the Willamette River bank.

Confined or semi-confined groundwater is found in the alluvial black and dark gray-brown sands of the intermediate groundwater zone below the four uppermost alternating sand and silt layers. The intermediate groundwater zone occurs between depths of approximately 36 to 46 feet bgs in the Acid Plant and Chlorate Plant areas. The intermediate groundwater zone has a saturated thickness of approximately 5 to 10 feet. The shallow and intermediate groundwater zones are separated by a continuous silt horizon (approximately 6 inches to 4 feet thick). This silt horizon becomes discontinuous in the eastern portion of the Chlorate Plant Area, adjacent to the Willamette River.

The deep groundwater zone is found in the finer-grained deposits below the alluvial sands and above the Columbia River Basalt. Below the sands, at depths of approximately 40 to 45 feet bgs, silt with some clay and fine sand is predominant. Because of the fine-grained nature of these deposits, groundwater is not expected to be readily transmitted through these deeper deposits.

Basalt-zone groundwater is situated beneath the alluvial deposits at the Site up to the maximum depth explored in the RI (approximately 70 feet bgs).

3.4.2 Groundwater Flow Directions and Hydraulic Gradients

In general, the groundwater flow direction across the Site is toward the Willamette River. The shallow groundwater surface fluctuates seasonally, rising during periods of high rainfall and infiltration and decreasing during mid- to late summer and low rainfall periods. Shallow groundwater in close proximity to the Willamette River will rise in direct response to large increases in Willamette River stage (e.g., during a flood). In general, these short-term perturbations do not affect shallow groundwater flow directions with the exception of short-term groundwater flow reversals in close proximity to the river.

3.4.2.1 *Groundwater Flow Directions – Acid Plant Area*

Groundwater flow direction has been inferred for the shallow, intermediate, and deep groundwater zones. Groundwater elevation and flow data in the Acid Plant Area are available dating back to December 1996. Groundwater flow direction in the shallow zone is more variable than in the intermediate zone. In the Acid Plant Area, the shallow groundwater flow direction has been observed to vary from east to northeast. Intermediate-zone groundwater flow direction has been observed to be more consistent, in a direction of plant east-northeast. Figures 3-6 and 3-7 show variations in groundwater flow directions for the shallow and intermediate zones in the Acid Plant Area from June 1999 to June 2003.

3.4.2.2 *Groundwater Flow Directions – Chlorate Plant Area*

Groundwater elevation data are available for the Chlorate Plant Area dating back to October 2001. Groundwater flow direction in the shallow zone in this area is generally to the east-southeast. Groundwater flow direction in the intermediate zone in the Chlorate Plant Area is generally to the east-southeast. Figures 3-8 and 3-9 show the groundwater flow directions for the shallow and intermediate groundwater zones for the Chlorate Plant Area for April 2002 and June 2003.

3.4.2.3 *Groundwater Flow Directions – Deep Groundwater Zone*

Groundwater flow direction in the deep zone is based on data collected in February 1999, including data collected from an off-site well (MW-4d, located on the Rhone-Poulenc facility, upgradient of the Site) and from monitoring well W-19d, located on Lot 1. The groundwater flow direction for the deep zone is east-northeast. Figure 3-10 shows the potentiometric surface for groundwater in the deep groundwater zone, measured in February 1999.

3.4.2.4 *Groundwater Hydraulic Gradients*

Horizontal hydraulic gradients in the shallow groundwater zone have ranged from approximately 2.4×10^{-3} (November 2001) to 6.9×10^{-3} feet/feet (February 1999). Gradients in the intermediate groundwater zone have generally been more consistent and have ranged from approximately 3.8 x 10^{-3} (June 1999) to 6.9 x 10^{-3} feet/feet (September 1999).

Vertical hydraulic gradients have been calculated for monitoring well clusters. Vertical hydraulic gradients between shallow- and intermediate-zone wells were calculated for the following monitoring well pairs: MWA-2/MWA-8i, MWA-3/MWA-9i, MWA-4/MWA-10i, MWA-5/MWA-14i, MWA-6r/MWA-16, and MWA-7/MWA-12i. Vertical hydraulic gradients varied widely over the duration of the investigation, from 5.23 feet downward to 2.04 feet upward over vertical distances of 9.6 to 18.3 feet (based on the distances between the midpoints of the well screens). Variations in vertical hydraulic gradients were more pronounced along the eastern edge of the Site (i.e., along the Willamette River). All but one of the well clusters exhibited primarily downward hydraulic gradients. Wells MWA-5/MWA-14i exhibited primarily upward hydraulic gradients. The nested well pair on the western edge of the Site (MWA-7/MWA12i) exhibited only downward gradients, whereas upward gradients were observed at one time or another in other shallow- and intermediate-zone well pairs.

Intermediate- and deep-zone monitoring well pairs (MWA-9i/MWA-13d and MWA-32i/MWA-31i) exhibited vertical hydraulic gradients between 1.96 feet downward and 0.40 feet upward over vertical distances of 9.5 to 18.0 feet. These vertical gradients represent a less pronounced variation in groundwater elevations at depth.

Vertical hydraulic gradients between the deep and basalt wells (MWA-13d/MWA-21b) were observed to be upward and ranged from 0.10 feet to 0.35 feet over a vertical distance of approximately 13 feet (based on the distances between the midpoints of the well screens).

Only upward gradients were observed for the nested monitoring well pair in the Chlorate Plant Area (MWA-25/MWA-28i). Upward gradients for this well pair ranged from 0.8 feet to 1.7 feet over a vertical distance of 27.6 feet. Although monitoring well MWA-28i is designated as an intermediate-zone well, it is screened in the deepest silt layer observed at the Site, above the bedrock basalt.

3.4.3 *Tidal Influence Monitoring*

The tidal influence study, conducted 3 to 8 February 1999, provides a general understanding of the effects that tidal and river stage fluctuations in the Willamette River have on the groundwater flow system at the Site.

During the period of tidal monitoring, the Willamette River stage ranged from about 11 to 13 feet (City of Portland Datum) and daily tidal fluctuations generally ranged from 0.5 and 1.0 feet, measured in the Willamette River, adjacent to the Site. During this period, shallow-zone groundwater levels were not affected by fluctuations in the river, whereas intermediate- and deep-zone groundwater levels exhibited some influence from Willamette River tidal fluctuations up to 300 feet from the river. Figure 3-11 is a hydrograph of clustered shallow-, intermediate-, and deep-zone groundwater monitoring wells located less than 100 feet from the river. The hydrograph clearly shows the separation between the shallow potentiometric surface (at MWA-3) and the intermediate- and deep-zone potentiometric surfaces (e.g., at wells MWA-9i and MWA-13d). The intermediate- and deep-zone potentiometric surfaces closely emulate the fluctuations in the Willamette River. It should be noted that the river surface is about 2 feet lower in elevation than the intermediate/deep groundwater surfaces during the monitoring period, indicating that the river stage does not substantially affect groundwater flow directions. A dampening and lag in the arrival time of the tidal 'peaks' can also be observed in the hydrograph, which illustrates the attenuation of the propagating pressure wave from the river to the groundwater monitoring wells.

Figure 3-12 shows the degree of influence that river stage fluctuations have on the intermediate-zone wells progressively further inland from the river. During the monitoring period, the Willamette River stage exhibited fluctuations on the order of 1 to 2 feet. Approximately 90 feet from the shoreline, MWA-9i exhibited groundwater elevation fluctuations on the order of 0.5 feet. Approximately 300 feet from the shoreline, tidal influences were still observed in MWA-11i, although slightly dampened, relative to MWA-9i. At monitoring well MWA-12i, approximately 900 feet from the shoreline, there was no evidence of influence from river stage fluctuations during the monitoring period.

Results of the tidal influence monitoring suggest that Willamette River fluctuations are propagated inland through the intermediate and deep groundwater zones, but do not significantly alter the groundwater flow system at the Site.

3.4.4 *Hydraulic Conductivity Estimates*

Slug tests were conducted in 12 monitoring wells to estimate the hydraulic conductivity of the shallow, intermediate, and deep groundwater zones. A description of the hydraulic conductivity testing is provided in the *Elf Atochem Acid Plant Area Remedial Investigation Interim Data Report* (Exponent 1999). Results from the slug tests are presented in Table 3-3. Based on the results, shallow-zone horizontal hydraulic conductivity ranges from 5.9 feet/day in MWA-7 to 34 feet/day in MWA-5, with a mean value of 17 feet/day. Data collected from MWA-6 were inconclusive and were not used in the estimation of hydraulic conductivity for the shallow zone. Monitoring well MWA-6 was abandoned and replaced by MWA-6r in August 1999.

Estimates of intermediate-zone horizontal hydraulic conductivities range from 0.04 feet/day in MWA-12i to 21 feet/day in MWA-9i, with a geometric mean value of 5.8 feet/day. Aquifer test data from monitoring well MWA-10i exhibited a rapid response, indicating that the test only evaluated the annular space surrounding the monitoring well. Data from MWA-10i were not used to estimate the hydraulic conductivity of the intermediate groundwater zone.

Slug test data collected from well MWA-13d in the deep groundwater zone indicate a horizontal hydraulic conductivity of 0.3 feet/day.

4.0 RESULTS OF REMEDIAL INVESTIGATION SAMPLING

This section presents a summary of analytical results for soil, groundwater, and storm water samples collected during the RI and groundwater monitoring events. The extent of contamination is summarized in Section 5.0. Section 5.0 also discusses the conceptual site model.

4.1 SOIL SAMPLING RESULTS

During the RI field activities, soil samples were collected from the following locations at the Site:

- Three unpaved area soil sampling borings (US-01 through US-03, Table 2-1, Figure 2-1);
- Fifty-seven of the 74 soil sampling borings (B-49 through -58; B-61, -62, -65, -66; B-71 through -84; B-86 through –88; and B-91 through –115, Table 2-1, Figure 2-1);
- Thirty-nine of the 81 IRM borings (IB-4, -6, -17, -20, -21, -25 through -27; IB-32, -36, -37, -39, -41, -43, -44, -46 through -48; IB-51, -73, -74, -77, -79 through -91; and IB-93 through IB-96, Table 2-2, Figure 2-2);
- Thirty-two VES borings (AP-1 through AP-8 and VP-1 through VP-24, Table 2-3, Figure 2-3);
- Eleven of the 34 monitoring well borings (MWA-8i through MWA-13d; MWA-15; MWA-18 through MWA-20; and MWA-30, Table 2-4, Figure 2-4);
- Seven surface soil sampling locations (S-2 through S-8, Figure 2-5); and
- Six riverbank soil sampling locations (RB-7 through RB-12, Figure 2-6).

Soil samples were analyzed for organochlorine pesticides, VOCs, SVOCs, petroleum hydrocarbons, metals, and physical parameters as presented in Tables 2-1 through 2-4 and described in Section 2.0. Physical parameters are discussed in Section 3.0.

The discussion of analytical results for soil centers on a focused list of site-specific COIs. These COIs were selected based on their historical use or production at the Site, their general frequency of detection, and the results of the Preliminary Assessment prepared for the Site. The focused list of COIs includes the following constituents:

- DDT and its metabolites, 1,1-dichloro-2,2- bis(p-chlorophenyl)ethane (DDD) and DDE;
- Chlorobenzene; and
- Chromium.

Other COIs detected in soil are not discussed in detail; however, complete analytical results are presented in the soil analytical results summary tables (Tables 4-1 through 4-18). All COIs detected in the RI will be evaluated in the Baseline Risk Assessment.

4.1.1 Unpaved Area Soil Sampling Borings

Six soil samples from the three unpaved area soil sampling borings shown on Figure 2-1 were collected and analyzed for organochlorine pesticides by USEPA Method 8081A.

DDT concentrations in the samples ranged from 0.239 mg/kg (US-02, 2 to 2.5 feet bgs) to 690 mg/kg (US-01, 2 to 2.5 feet bgs). DDT concentrations in surface soils (zero to 0.5 feet bgs) ranged from 1.9 mg/kg (US-02) to 140 mg/kg (US-03), whereas DDT concentrations in samples collected from 2 to 2.5 feet bgs ranged from 0.239 (US-02) to 690 mg/kg (US-01). DDD and DDE were also detected in most of the unpaved soil samples, at concentrations approximately one order of magnitude lower than DDT concentrations for each sample. No other pesticides were detected in the unpaved area soil samples. Analytical results for organochlorine pesticides in unpaved area soils are summarized in Table 4-1. Analytical results for DDT, DDD, and DDE in unpaved area soil samples are shown in Figure 4-1.

The unpaved area where these samples were collected was addressed in the Phase I IRM by installation of a temporary cover system (ERM 2001c). The Phase I and II IRMs are discussed in Section 6.0.

4.1.2 *Soil Sampling Borings*

4.1.2.1 Organochlorine Pesticides

One hundred six samples from 39 soil sampling borings were collected and analyzed for organochlorine pesticides by USEPA Method 8081A. Six of the 106 samples were duplicate samples. Soil sampling boring locations are shown on Figure 2-1.

DDT was detected in 93 of the 106 samples. DDT concentrations ranged from 0.020 mg/kg (boring number B-50) to 16,000 mg/kg (boring number B-53). DDD and DDE were detected at approximately one order of magnitude less than the DDT concentration in most of the soil sampling boring samples. Concentrations of DDD and DDE ranged from 0.0026 to 620 mg/kg and 0.0084 to 190 mg/kg, respectively. Analytical results for organochlorine pesticides in soil sampling boring samples are summarized in Table 4-1. Analytical results for DDT, DDD, and DDE in soil sampling boring samples are shown on Figures 4-1 and 4-2.

The highest concentrations of DDT were detected in the vicinity of the Acid Plant Area, specifically in and adjacent to the former DDT process building, in and around the former MPR pond and adjacent to the No. 2 Warehouse. In general, the concentrations were highest in shallow soil (zero to 8 feet bgs) and decreased with depth.

Four other pesticide compounds were detected in three samples collected from soil sampling borings. The compounds delta-BHC, gamma-BHC (lindane), gamma-chlordane, and methyloxychlor were detected in borings B-57 (4 to 5 feet bgs), B-61 (5 to 6 feet bgs), and B-99 (zero to 0.5 feet bgs).

One sample was subjected to Synthetic Precipitation Leaching Procedure (SPLP) analysis for pesticides (boring B-53 at 4.5 to 6 feet bgs). This sample contained the greatest DDT concentration in samples collected from the borings (16,000 mg/kg). Boring B-53 was located in the former MPR pond in the Acid Plant Area. The SPLP DDT concentration in the sample was 9 micrograms per liter (μg/L). Table 4-2 contains the analytical results for the total and SPLP pesticide analyses for boring B-53.

Soil from the areas where 26 of the 93 soil samples with DDT detections were collected was removed during the Phase I and II IRMs, including the sample collected from boring B-53, which contained DDT at a concentration of 16,000 mg/kg. The Phase I and II IRMs are discussed in Section 6.0.

4.1.2.2 Volatile Organic Compounds

Forty-five samples from 21 borings were collected and analyzed for VOCs by USEPA Method 8260B. Three of the 45 samples were duplicate samples.

Chlorobenzene was detected in 15 of the 45 samples analyzed for VOCs, at concentrations ranging from 0.0011 mg/kg (boring B-100, 0.5 to 1.5 feet bgs) to 4,100 mg/kg (boring B-55, 6 to 7 feet bgs). The highest concentrations of chlorobenzene were observed in borings B-55 (4,100 mg/kg) and B-100 (1,800 and 2,600 mg/kg), which were located in and adjacent to the former DDT process building. Analytical results for VOCs in soil samples collected from soil sampling borings are summarized in Table 4-3. Analytical results for chlorobenzene in soil sampling borings are shown on Figures 4-3 and 4-4.

Five other VOCs (acetone, chloroform, tetrachloroethene, toluene, and trichloroethene) were detected in eight soil samples collected from the soil sampling borings.

One sample was subjected to SPLP analysis for VOCs (boring B-53 at 4.5 to 6 feet bgs). Boring B-53 was located in the former MPR pond in the Acid Plant Area. The total and SPLP chlorobenzene concentrations in the sample were 1,400 mg/kg and 44 μg/L, respectively. Table 4-4 contains the analytical results for the total and SPLP VOC analyses for boring B-53.

4.1.2.3 Chromium

Eighty-six samples from 18 soil sampling borings were collected and analyzed for total chromium by USEPA Method 6020. Five of the 86 samples were duplicate samples. In addition, five of the 86 samples were analyzed for hexavalent chromium by USEPA Method 3060A.

Chromium was detected in all 86 samples, at concentrations ranging from 10 mg/kg (boring B-87, 12 to 16 feet bgs) to 1,600 mg/kg (boring B-88, 10 to 12 feet bgs). The highest concentrations were detected in samples collected from borings located in and around the Chlorate Cell Room.

Hexavalent chromium was detected in four of the five samples analyzed, at concentrations ranging from 9.7 mg/kg (boring B-75, 8 to 10 feet bgs) to 69 mg/kg (boring B-77, 8 to 10 feet bgs). Analytical results for total and hexavalent chromium in soil samples collected from soil sampling borings are summarized in Table 4-5 and shown on Figures 4-5 and 4-6.

4.1.3 Interim Remedial Measure Borings

Borings for the Phase II Soil Removal IRM were installed in the Acid Plant Area, in areas of known or expected high pesticide and VOC concentrations. More than half of the borings were completed in soils subsequently removed during the IRM. IRM boring locations are shown on Figure 2-2.

4.1.3.1 Organochlorine Pesticides

Forty-five samples from 36 IRM borings were collected and analyzed for organochlorine pesticides by USEPA Method 8081A. Two of the 45 samples were duplicate samples.

DDT was detected in all 45 soil samples at concentrations ranging from 0.0074 mg/kg (boring IB-84, 5 to 6 feet bgs) to 13,000 mg/kg (boring IB-20, 3 to 4 feet bgs). DDD and DDE were also detected in a majority of the IRM boring soil samples, at concentrations approximately one to two orders of magnitude lower than the DDT detection in each sample. Analytical results for organochlorine pesticides in IRM boring soil samples are summarized in Table 4-6. Analytical results for DDT, DDD, and DDE in IRM boring soil samples are shown on Figures 4-7 and 4-8.

One other pesticide constituent, endrin, was detected in one IRM boring soil sample (boring IB-32, zero to 1 foot bgs) at a concentration of 1.5 mg/kg. The DDT concentration in this sample was 2,700 mg/kg.

Soil from the areas where 19 of the 45 soil samples with DDT detections were collected was removed during the Phase I and II IRMs. The Phase I and II IRMs are discussed in Section 6.0.

4.1.3.2 Volatile Organic Compounds

One sample from each of three IRM borings was analyzed for VOCs by USEPA Method 8260B. Each sample was a composite of soil from zero to

10 feet bgs in each boring. Chlorobenzene was the only VOC detected in the three soil samples at estimated concentrations ranging from 2,900 mg/kg (boring IB-26) to 8,800 mg/kg (boring IB-21). Analytical results for VOCs in IRM boring soil samples are summarized in Table 4-7. Analytical results for chlorobenzene in IRM boring soil samples are shown on Figure 4-9.

Additionally, each sample was subjected to TCLP analysis for VOCs. The total and TCLP chlorobenzene concentrations for each sample were 8,800 mg/kg and 180 milligrams per liter (mg/L) (boring IB-21), 2,900 mg/kg and 100 mg/L (boring IB-26), and 3,000 mg/kg and 110 mg/L (boring IB-51). Table 4-8 contains the analytical results for the total and TCLP VOC analyses for IRM boring soil samples.

4.1.3.3 Metals

One soil sample from one IRM boring (boring IB-44, zero to 1 foot bgs) was analyzed for four metals (cadmium, total chromium, lead, and zinc) by USEPA Method 6010B. Total chromium, lead, and zinc were detected in the sample at concentrations of 85.7, 47.9, and 394 mg/kg, respectively. Table 4-9 presents the analytical results for metals in the IRM boring sample.

4.1.4 Vapor Extraction System Borings

Borings for the VES were installed in the former Monochlorobenzene Recovery Unit Area. High concentrations of pesticides and chlorobenzene were expected in this area. VES boring locations are shown on Figure 2-3.

4.1.4.1 Organochlorine Pesticides

Fourteen soil samples from eight VES borings were collected and analyzed for organochlorine pesticides by USEPA Method 8081A. One of the 14 samples was a duplicate sample. Eight of the 14 samples were only analyzed for DDT, DDD, and DDE (i.e., not the entire suite of organochlorine pesticides).

DDT was detected in all 14 samples at concentrations ranging from 0.150 mg/kg (boring VP-22, 14 to 16 feet bgs) to 2,600 mg/kg (boring AP-3, 8 to 10 inches bgs). DDD was detected in 13 of the 14 VES boring soil samples, whereas DDE was detected in six of the 14 VES boring soil samples. Both DDD and DDE were detected at approximately one to two orders of magnitude less than the respective DDT concentrations. Results of pesticide analyses conducted on soil samples collected from VES borings are summarized in Table 4-10.

One other pesticide, endrin, was detected in three of the six samples in which it was analyzed. Endrin was detected at approximately 70 mg/kg in the samples collected from VES borings AP-2 (zero to 4 inches bgs) and AP-5 (zero to 2 inches bgs, and its duplicate sample).

Soil in the vicinity of six of the eight VES borings from which samples were collected was removed during the Phase II IRM. The Phase II IRM is discussed in Section 6.0.

4.1.4.2 Volatile Organic Compounds

Sixty-seven soil samples from 32 VES borings were collected and analyzed for VOCs by USEPA Method 8260B. Two of the 67 samples were duplicate samples.

Chlorobenzene was detected in 63 of the 67 samples analyzed for VOCs at concentrations ranging from 0.31 mg/kg (boring VP-24, 11.5 to 12 feet bgs) to 13,000 mg/kg (boring VP-6, 7.5 to 8 feet bgs). Several other VOCs were detected in VES boring soil samples. In general, concentrations of the other VOCs were lower than the chlorobenzene concentration in each sample by approximately one to three orders of magnitude.

Analytical results for VOCs in soil samples collected from VES borings are summarized in Table 4-11. Analytical results for chlorobenzene in VES boring soil samples are shown on Figure 4-9.

Soil in the vicinity of seven of the 32 VES borings from which samples were collected was removed during the Phase I and II IRMs. Additionally, temporary cover (asphalt paving) was installed over soil in the vicinity of three additional VES borings as part of the Phase II IRM. The Phase I and II IRMs are discussed in Section 6.0.

4.1.5 Monitoring Well Borings

4.1.5.1 Organochlorine Pesticides

Fourteen soil samples from six monitoring well borings were collected and analyzed for organochlorine pesticides by USEPA Method 8081A. One of the 14 soil samples was a duplicate sample. Monitoring well locations are shown on Figure 2-4.

DDT was detected in 13 of the 14 monitoring well boring soil samples at concentrations ranging from 0.014 mg/kg (well MWA-20, 15 to 16.5 feet bgs) to 31,000 mg/kg (well MWA-11i, 6 to 8 feet bgs). Monitoring well MWA-11i was installed in the center of the Acid Plant Area where high DDT concentrations were expected. DDD and DDE were detected in 11 and 12 monitoring well boring soil samples, respectively. In general, DDD and DDE concentrations were one to two orders of magnitude lower than the respective DDT concentrations. No other pesticides were detected in the monitoring well boring soil samples. Results of pesticide analyses conducted on soil samples collected from monitoring well borings are summarized in Table 4-12.

4.1.5.2 Volatile Organic Compounds

Five soil samples from three monitoring well borings were collected and analyzed for VOCs by USEPA Method 8260B. Monitoring well locations are shown on Figure 2-4.

Chlorobenzene was detected in four of the five monitoring well boring soil samples at concentrations ranging from 39.0 mg/kg (well MWA-11i, 28 to 30 feet bgs) to 15,000 mg/kg (well MWA-11i, 6 to 8 feet bgs). Monitoring well MWA-11i was installed in the center of the Acid Plant Area where high chlorobenzene concentrations were expected. Analytical results for VOCs in monitoring well boring soil samples are summarized in Table 4-13.

In addition to chlorobenzene, four other VOCs were detected at low concentrations in two of the five monitoring well boring soil samples (1,1,1-trichloroethane, chloroform, ethylbenzene, and xylenes in monitoring well borings MWA-11i and MWA-30).

4.1.5.3 *Petroleum Hydrocarbons*

One soil sample was collected from a monitoring well boring and analyzed for diesel-, gasoline-, and residual-range organics by Northwest Methods NWTPH-Dx and NWTPH-Gx. The sample was collected from monitoring well MWA-30 at a depth of 29.5 to 30 feet bgs. Collection of this soil sample was prompted by the observation of a 3-inch thick layer of dark, oily sand with a hydrocarbon odor at a depth of 29 feet bgs in this boring. Monitoring well MWA-30 is located adjacent to the northeastern corner of the salt pads, adjacent to the Willamette River bank (Figure 2-4). The dark, oily sand was not observed in monitoring wells MWA-19 and MWA-34i to the north, MWA-29 to the south, or MWA-27 to the west.

Diesel-, gasoline-, and residual-range organics were detected in the sample at concentrations of 29,000, 150, and 40,000 mg/kg, respectively. Table 4-14 presents the results of the petroleum hydrocarbon analyses on this monitoring well boring soil sample.

4.1.6 *Surface Soil Samples*

4.1.6.1 *Organochlorine Pesticides*

Eight samples from seven surface soil sampling locations were collected and analyzed for organochlorine pesticides by USEPA Method 8081A. One of the eight samples was a duplicate sample. Surface soil sampling locations are shown on Figure 2-5.

DDT was detected in all eight samples at concentrations ranging from 0.330 mg/kg (location S-2, zero to 4 inches bgs) to 1,600 mg/kg (locations S-7 and S-8, zero to 4 inches bgs). The highest DDT concentrations were detected in the samples collected from within the Acid Plant Area (sample locations S-6, S-7, and S-8). Soil from which these samples were collected was removed during the Phase II IRM.

DDD and DDE were also detected in all of the surface soil samples. Within the Acid Plant Area, DDD and DDE concentrations were approximately one to two orders of magnitude less than the respective DDT concentrations. Outside the Acid Plant Area, DDD and DDE concentrations were approximately equal to or one order of magnitude less than the respective DDT concentrations.

One other pesticide, Methoxychlor, was detected in the duplicate sample from location S-3 (zero to 4 inches bgs) at a concentration of 0.0073 mg/kg. Methoxychlor was not detected in the primary sample from this location.

Analytical results for organochlorine pesticides in surface soil samples are summarized in Table 4-15. Analytical results for DDT, DDD, and DDE in surface soil samples are shown on Figure 4-10.

4.1.7 Riverbank Soil Samples

4.1.7.1 Organochlorine Pesticides

Seven soil samples from six riverbank sampling locations were collected and analyzed for organochlorine pesticides by USEPA Method 8081A. One of the seven samples was a duplicate sample. All samples were collected at a depth of zero to 0.5 feet bgs. Samples were collected from three paired locations with one sample location near the top of slope and the second location down slope from the first sample location. Riverbank soil sampling locations are shown on Figure 2-6.

DDT was detected in all seven riverbank soil samples at concentrations ranging from 2.3 mg/kg (RB-7) to 120 mg/kg (RB-10). The highest DDT concentrations were detected in the northernmost pair of sample locations (RB-9 and RB-10), with concentrations decreasing to the south. Additionally, for all paired sample locations, the concentration of DDT in the sample collected near the top of slope was higher than the DDT concentration in the down slope sample. Analytical results for organochlorine pesticides in riverbank soil samples are summarized in Table 4-16. Analytical results for DDT, DDD, and DDE in riverbank soil samples are shown on Figure 4-11.

One other pesticide, alpha-BHC, was detected in the sample from location RB-8 at a concentration of 0.11 mg/kg.

4.1.7.2 Semi-Volatile Organic Compounds

Seven soil samples from six riverbank sampling locations were collected and analyzed for SVOCs by USEPA Method 8270C. One of the seven samples was a duplicate sample. All samples were collected at a depth of zero to 0.5 feet bgs. Riverbank soil sampling locations are shown on Figure 2-6.

One of the seven soil samples contained detectable concentrations of 11 SVOCs (RB-8); concentrations ranged from 0.4 to 3.0 mg/kg. Table 4-17 presents a summary of SVOC analytical results for riverbank soil samples.

4.1.7.3 Metals

Seven soil samples from six riverbank soil sampling locations were collected and analyzed for four metals (cadmium, total chromium, lead, and zinc) by USEPA Method 6010B. Riverbank soil sampling locations are shown on Figure 2-6.

Cadmium was detected in two of the seven riverbank soil samples at concentrations of 1.22 mg/kg (RB-7) and 1.4 mg/kg (RB-12, duplicate sample). Chromium was detected in all seven riverbank soil samples at concentrations ranging from 17 mg/kg (RB-10) to 40.7 mg/kg (RB-8). Lead was detected in all seven riverbank soil samples at concentrations ranging from 45.7 mg/kg (RB-9) to 2,090 mg/kg (RB-8). Zinc was detected in all seven riverbank soil samples at concentrations ranging from 72.2 mg/kg (RB-10) to 212 mg/kg (RB-11). Table 4-18 presents the analytical results for metals in the riverbank soil samples.

4.2 GROUNDWATER SAMPLING RESULTS

During the RI, groundwater samples were collected as both grab samples from direct-push borings and from Site monitoring wells. Groundwater grab samples were collected from 33 direct-push borings (borings B-55, B-56, B-59 to B-61, B-64, B-65, B-67 to B-85, B-86b to B-88, B-90, and B-116 to B-118). Monitoring well groundwater samples were collected periodically, as described below.

Groundwater samples were analyzed for total and dissolved organochlorine pesticides, VOCs, SVOCs, petroleum hydrocarbons, metals, perchlorate, and other miscellaneous analytes as presented in Tables 2-1 through 2-4 and described in Section 2.0.

The discussion of analytical results for groundwater centers on a focused list of selected site-specific COIs. These COIs were selected based on their historical use or production at the Site, their frequency of detection, and the results of the Preliminary Assessment prepared for the Site. The focused list of COIs includes the following constituents:

- DDT and its metabolites, DDD and DDE;
- Chlorobenzene;
- Chromium;
- Perchlorate; and
- Chloride.

Other COIs detected in groundwater are not discussed in detail. The complete list of COIs is discussed in Section 5.1 and the groundwater analytical results are presented in Tables 4-19 through 4-30. All COIs detected in the RI will be evaluated in the Baseline Risk Assessment.

4.2.1 Groundwater Grab Sampling

Groundwater grab samples were collected from select direct-push borings upon completion of each boring. Direct-push boring locations are shown on Figure 2-1.

4.2.1.1 Organochlorine Pesticides

One groundwater grab sample was collected from boring B-59 for analysis of organochlorine pesticides by USEPA Method 8081A. Boring B-59 was located adjacent to the northwestern corner of the Chlorine Finishing Building, west of the Acid Plant Area. No pesticides were detected in the groundwater grab sample collected at boring B-59. Table 4-19 presents a summary of the analytical results for organochlorine pesticides in this sample.

4.2.1.2 Volatile Organic Compounds

Nine groundwater grab samples from eight borings were collected and analyzed for VOCs by USEPA Method 8260B. One of the nine groundwater grab samples was a duplicate sample. Eight of the nine samples were analyzed for an abbreviated list of VOCs (see Table 4-20 for the list of analytes). The remaining sample (from boring B-59) was analyzed for the full VOC list of compounds.

Five VOCs were detected in four of the groundwater grab samples. All detections were at low concentrations, with the highest detection of

330 μg/L for acetone in the sample from boring B-59. Chlorobenzene was not included in the abbreviated analyte list and was not detected in the groundwater grab sample collected at boring B-59. Table 4-20 presents a summary of VOC analytical results for the nine groundwater grab samples.

4.2.1.3 *Semi-Volatile Organic Compounds*

One groundwater grab sample was collected from boring B-59 for analysis of SVOCs by USEPA Method 8270-SIM. Boring B-59 was located adjacent to the northwestern corner of the Chlorine Finishing Building, west of the Acid Plant Area. Seven SVOC compounds were detected in the sample; the highest concentrations were benzoic acid (34 μg/L) and phenol (45 μg/L). Table 4-21 presents a summary of the analytical results for SVOCs in this groundwater grab sample.

4.2.1.4 *Petroleum Hydrocarbons*

One groundwater grab sample was collected from each of two direct-push borings and analyzed for diesel-range organics by Northwest Method TPH-Dx (borings B-55 and B-56). These borings were located at the southern end of the Acid Plant Area, near the southwestern corner of No. 3 Warehouse. Diesel-range petroleum hydrocarbons were not detected in either groundwater grab sample. Table 4-22 presents the analytical results for petroleum hydrocarbons in these samples.

4.2.1.5 *Chromium*

Thirty groundwater grab samples from 25 direct-push borings were collected and analyzed for chromium by USEPA Methods 6010B (borings B-68 to B-84) and 6020 (borings B-85 to B-118). Four of the 30 samples were duplicate samples.

Chromium was detected in 23 of the 30 groundwater grab samples at concentrations ranging from 0.0255 mg/L (boring B-68, 31 to 36 feet bgs) to 110 mg/L (boring B-80, 16 to 20 feet bgs). The highest chromium concentrations were observed in samples collected from borings in or adjacent to the Chlorate Cell Room and the salt pad east of the Chlorate Cell Room. Shallow-zone monitoring well MWA-33 was installed adjacent to boring B-80, inside the Chlorate Cell Room. The groundwater sample collected from MWA-33 in June 2003 contained chromium at a concentration of 0.601 mg/L, approximately two orders of magnitude lower than the estimated ("J") concentration measured in the sample collected from direct-push boring B-80. This result suggests that the concentration of chromium in the groundwater sample collected from boring B-80 may be erroneously high. Chromium was not detected in the groundwater grab sample collected from boring B-77 (detection limit 0.029 mg/L, 28 to 32 feet bgs). This boring was advanced within a few feet of boring B-76, which contained chromium in a groundwater grab sample at a concentration of 21 mg/L (15 to 19 feet bgs).

Analytical results for chromium in groundwater grab samples are summarized in Table 4-23.

4.2.1.6 Conventional Parameters

Four groundwater grab samples from two direct-push borings were collected and analyzed for ammonia as nitrogen by USEPA Method 350.1. The four samples represent two primary samples and two duplicate samples. Ammonia as nitrogen was detected at concentrations of 1.22 and 1.28 mg/L for the primary and duplicate samples from boring B-67 and at 2.0 mg/L for both the primary sample and its duplicate from boring B-119. Borings B-67 and B-119 were advanced downgradient and upgradient, respectively, of the former Ammonia Manufacturing Plant. The Ammonia Manufacturing Plant was situated in the same area as the southern portion of the caustic tank farm shown on Figure 2-1.

Table 4-24 presents the results for conventional analyses conducted on these groundwater grab samples.

4.2.2 Monitoring Well Groundwater Sampling

Groundwater samples were collected from existing site monitoring wells during eight sampling events over the course of the RI:

- January 1999;
- April 1999;
- August 1999;
- November 1999;

- March 2001;
- June 2001;
- April 2002; and
- June and July 2003.

Groundwater samples were analyzed for total and dissolved organochlorine pesticides, VOCs, SVOCs, petroleum hydrocarbons, metals, perchlorate, and conventional parameters, including total chloride. A summary of monitoring well sample information (well number, date, list of analytes) is presented in Table 2-7. Monitoring well locations are shown on Figure 2-4.

In the discussion below, monitoring well groundwater sampling results are presented by groundwater zone (i.e., shallow, intermediate, deep, and basalt) and then by family of analytes (i.e., organochlorine pesticides, VOCs, SVOCs, metals, etc.).

4.2.2.1 *Shallow-Zone Groundwater Analytical Results*

Total and Dissolved Organochlorine Pesticides

Ninety-three samples from 24 shallow-zone monitoring wells were collected during eight groundwater sampling events and analyzed for total organochlorine pesticides by USEPA Method 8081A. Six of the 93 samples were duplicate samples.

Total DDT was detected in 37 of the 93 samples at concentrations ranging from 0.01 μg/L (MWA-30, 12 April 2002) to 450 μg/L (MWA-15r, 30 March 2001). Monitoring well MWA-30 is situated downgradient of the Chlorate Plant Area, approximately 800 feet cross-gradient from the Acid Plant Area. Monitoring well MWA-15r is situated within the footprint of the former MPR pond. The mean concentration of the total DDT in the six groundwater samples collected from MWA-15 and MWA-15r is approximately two orders of magnitude greater than the mean total DDT concentration for the 31 other groundwater samples collected from the 22 other shallow-zone monitoring wells.

Total DDD and DDE were also detected in some of the 93 groundwater samples collected from the 24 shallow-zone monitoring wells. Total DDD was detected in 39 of the 93 samples, whereas total DDE was detected in 20 of the 93 samples. Total DDD and DDE concentrations were similar in magnitude to total DDT concentrations for most monitoring wells. In monitoring wells MWA-15 and MWA-15r, total DDD and DDE concentrations were approximately one order of magnitude less than the respective DDT concentration.

Seven other pesticides were detected in unfiltered shallow-zone monitoring well groundwater samples: alpha-BHC, alpha-chlordane, dieldrin, endosulfan I, endosulfan sulfate, gamma-BHC (lindane), and heptachlor epoxide. Concentrations of these constituents ranged from 0.05 μg/L (MWA-2, 27 April 1999, duplicate sample, gamma-BHC [lindane]) to 420 μg/L (MWA-15r, 16 April 2002, alpha-BHC).

Twenty-three samples from nine shallow-zone monitoring wells were collected during three groundwater sampling events and analyzed for dissolved organochlorine pesticides by USEPA Method 8081A. Two of the 23 samples were duplicate samples.

Dissolved DDT was detected in nine of the 23 shallow-zone monitoring well groundwater samples at concentrations ranging from 0.05 μg/L (MWA-3, 24 August 1999) to 11 μg/L (MWA-15, 26 August 1999). Monitoring well MWA-3 is located downgradient of the Acid Plant Area; monitoring well MWA-15 is located within the former MPR pond. Dissolved DDD was detected in eight of the 23 samples and dissolved DDE was detected in four of the 23 samples. Dissolved DDD and DDE concentrations were similar (typically within one order of magnitude) to dissolved DDT concentrations.

Two other dissolved pesticides, dieldrin and gamma-BHC (lindane), were detected in four shallow-zone monitoring well groundwater samples. These constituents were detected in monitoring wells MWA-2, MWA-3, MWA-4, and MWA-6 during three different sampling events. Concentrations of these constituents ranged from 0.05 to 0.6 μg/L.

A summary of analytical results for total and dissolved organochlorine pesticides in monitoring well groundwater samples is provided in Table 4-25. Analytical results for DDT in shallow-zone groundwater from the June 2003 sampling event are shown on Figure 4-12.

Volatile Organic Compounds

Eighty-nine samples from 24 shallow-zone monitoring wells were collected during eight groundwater sampling events and analyzed for VOCs by USEPA Method 8260B. Five of the 89 groundwater samples were duplicate samples.

Chlorobenzene was detected in 62 of the 89 shallow-zone groundwater samples at concentrations ranging from 0.99 μg/L (MWA-7, 26 March 2001) to 260,000 μg/L (MWA-15r, 30 March 2001). Monitoring well MWA-7 is located along the western edge of the ATOFINA Chemicals property, approximately 1,000 feet upgradient of the Acid Plant Area. Monitoring well MWA-15r is located within the footprint of the former MPR pond. The chlorobenzene concentration in the most recent sample collected from monitoring well MWA-15r (June 2003) was 13,300 μg/L.

In monitoring wells where chlorobenzene has routinely been detected, the highest chlorobenzene concentrations were generally observed in samples collected during the April 2002 groundwater sampling event. Additionally, for monitoring wells in which chlorobenzene was detected in the two most recent groundwater sampling events (April 2002 and June 2003), chlorobenzene concentrations were lower in eight of the 10 shallow-zone monitoring wells for the most recent sampling event (June 2003), indicating a general downward trend in chlorobenzene concentrations.

Twenty-six other VOCs were detected in samples collected from shallow-zone groundwater monitoring wells. Concentrations of these constituents ranged from 0.5 to 1,000 μg/L, with most concentrations in the range of 0.5 to 25 μg/L.

A summary of analytical results for VOCs in monitoring well groundwater samples is provided in Table 4-26. Analytical results for chlorobenzene in shallow-zone groundwater from the June 2003 sampling event are shown on Figure 4-13.

Semi-Volatile Organic Compounds

Fifty-four samples from 16 shallow-zone groundwater monitoring wells were collected during six groundwater sampling events and analyzed for SVOCs by USEPA Method 8270C or 8270-SIM. Three of the 54 samples were duplicate samples.

Thirty SVOCs were detected in 38 shallow-zone groundwater samples. Of those 30 compounds, the five most prevalent (in frequency and concentration) were: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3- and 4-chlorophenol, and benzoic acid. These constituents were detected at concentrations ranging from 0.1 to 290 μg/L, with the highest concentrations observed in monitoring wells MWA-15 and MWA-15r. The 25 other SVOCs were detected at relatively low concentrations that were generally at, or slightly greater than, method detection limits.

A summary of analytical results for SVOCs in monitoring well groundwater samples is provided in Table 4-27. Monitoring well locations are shown on Figure 2-4.

Petroleum Hydrocarbons

One groundwater sample collected from monitoring well MWA-30 on 4 June 2003 was analyzed for diesel- and heavy oil-range petroleum hydrocarbons by Method NWTPH-Dx. Collection of this groundwater sample was prompted by the observation of a 3-inch thick layer of dark, oily sand with a hydrocarbon odor at a depth of 29 feet bgs in this boring. Diesel-range petroleum hydrocarbons were detected in this sample at a concentration of 0.642 mg/L. Heavy-oil range petroleum hydrocarbons were not detected in this sample.

A summary of analytical results for petroleum hydrocarbons in monitoring well groundwater samples is provided in Table 4-28. Monitoring well locations are shown on Figure 2-4.

Metals

Seventy-one samples from 24 shallow-zone monitoring wells were collected during five groundwater sampling events and analyzed for various metals by USEPA Method 6010B or 6020. Six of the 71 shallow-zone groundwater samples were duplicate samples.

Thirty-one of the 71 samples were analyzed for total chromium. Chromium was detected in 26 of the 31 samples at concentrations ranging from 0.00117 mg/L (MWA-23, 4 June 2003) to 21 mg/L (MWA-27, 9 April 2002). Monitoring well MWA-27 is located downgradient of the Chlorate Plant Area, adjacent to the salt pads in the southeastern corner of the Site.

During the June 2001 groundwater sampling event, six shallow-zone groundwater samples analyzed for chromium were also analyzed for total hexavalent chromium. Hexavalent chromium was detected in two of the six samples (monitoring wells MWA-6r and MWA-20). Both wells are located downgradient of the Chlorate Plant Area. Total and hexavalent chromium concentrations for the sample collected from MWA-6r were 0.056 and 0.058 mg/L, respectively. Total and hexavalent chromium concentrations for the sample collected from MWA-20 were 0.097 and 0.060 mg/L, respectively. Because the concentrations of total and hexavalent chromium were similar, it was conservatively assumed that all chromium present in groundwater was hexavalent chromium. It was therefore decided that for future groundwater sampling events, only total chromium would be analyzed.

Shallow-zone groundwater samples were also analyzed for calcium, iron, magnesium, manganese, potassium, and sodium. Concentrations of these analytes were observed up to 567, 92.2, 48.5, 4.22, 9.4, and 1,860 mg/L, respectively.

A summary of analytical results for metals in monitoring well groundwater samples is provided in Table 4-29. Analytical results for chromium in shallow-zone groundwater for the June 2003 sampling event are shown on Figure 4-14.

Perchlorate

Sixteen groundwater samples from 13 shallow-zone monitoring wells were collected during the most recent groundwater sampling event (June and July 2003) and were analyzed for perchlorate by USEPA Method 314.0.

Perchlorate was detected in nine of the 16 samples at concentrations ranging from 0.32 mg/L (MWA-33, 11 June 2003) to 290 mg/L (MWA-25, 29 July 2003). Monitoring well MWA-33 is located inside the Chlorate Cell Room; MWA-25 is located immediately downgradient of the Chlorate Plant Area. Additionally, perchlorate was detected at a concentration of 210 mg/L in monitoring well MWA-27, which is slightly further downgradient of the Chlorate Plant Area than MWA-25.

A summary of analytical results for perchlorate in monitoring well groundwater samples is provided in Table 4-30. Analytical results for perchlorate in shallow-zone groundwater for the most recent groundwater sampling event (June and July 2003) are shown on Figure 4-15.

Conventional Parameters and Miscellaneous Constituents

Groundwater samples collected from shallow-zone monitoring wells were analyzed for a variety of conventional parameters and miscellaneous constituents, including: bicarbonate and carbonate alkalinity, total alkalinity, ammonia as nitrogen, sulfate, nitrate, nitrite, total organic carbon, chloral hydrate, p-chlorobenzenesulfonic acid (p-CBSA), total chloride, and dissolved methane. One-hundred two groundwater samples from 24 shallow-zone monitoring wells were analyzed for some combination of the above parameters. Five of the 102 groundwater samples were duplicate samples.

Ninety-four groundwater samples were analyzed for total chloride by USEPA Method 300.0. Total chloride concentrations in those samples ranged from 4 mg/L (MWA-3, 28 April 1999) to 190,000 mg/L (MWA-30, 12 April 2002, duplicate sample). Monitoring well MWA-30 is located in the southeastern portion of the Site, between the salt pads and the Willamette River bank. The highest chloride concentrations in the shallow-zone groundwater were observed in monitoring wells MWA-19, MWA-29, and MWA-30. All three of these wells are located adjacent to the salt pads in the southeastern corner of the Site.

A summary of analytical results for conventional parameters and miscellaneous constituents is provided in Table 4-30. Analytical results for chloride in shallow-zone groundwater for the June 2003 sampling event are shown on Figure 4-16.

4.2.2.2 *Intermediate-Zone Groundwater Analytical Results*

Total and Dissolved Organochlorine Pesticides

Seventy samples from 12 intermediate-zone monitoring wells were collected during eight groundwater sampling events and analyzed for total organochlorine pesticides by USEPA Method 8081A. Four of the 70 samples were duplicate samples.

Total DDT was detected in 18 of the 70 samples at concentrations ranging from 0.012 μg/L (MWA-8i, 10 April 2002) to 9 μg/L (MWA-9i, 28 January 1999). Monitoring wells MWA-8i and -9i are situated downgradient of the Acid Plant Area. Total DDD and DDE were also detected in some of the 70 groundwater samples collected from the 12 intermediate-zone monitoring wells. Total DDD was detected in 39 of the samples, whereas total DDE was detected in eight of the samples. Total DDD and DDE concentrations were similar in magnitude to total DDT concentrations for most monitoring wells.

Four other total pesticides were detected in intermediate-zone monitoring well groundwater samples: alpha-BHC, endrin, gamma-BHC (lindane), and heptachlor epoxide. Concentrations of these constituents ranged from 0.013 μg/L (MWA-11i, 15 June 2001, duplicate sample, alpha-BHC) to 0.428 μg/L (MWA-17si, 9 June 2003, heptachlor epoxide).

Twenty-one samples from eight intermediate-zone monitoring wells were collected during three groundwater sampling events and analyzed for dissolved organochlorine pesticides by USEPA Method 8081A. One of the 21 samples was a duplicate sample.

Dissolved DDT was detected in four of the 21 intermediate-zone monitoring well groundwater samples at estimated concentrations ranging from 0.6 μg/L (MWA-9i, 25 August 1999) to 8 μg/L (MWA-9i, 28 January 1999). Monitoring well MWA-9i is located downgradient of the Acid Plant Area. Dissolved DDD was detected in six of the 21 samples, and dissolved DDE was detected in three of the 21 samples. Dissolved DDD and DDE concentrations in those samples were similar (typically within one order of magnitude) to dissolved DDT concentrations.

One other dissolved pesticide, endosufan I, was detected in one intermediate-zone monitoring well groundwater sample. This constituent was detected in monitoring well MWA-8i during the January 1999 sampling event. The estimated concentration of endosufan I in this sample was 0.04 μg/L.

A summary of analytical results for total and dissolved organochlorine pesticides in monitoring well groundwater samples is provided in Table 4-25. Analytical results for DDT, DDD, and DDE in intermediate-zone groundwater for the June 2003 sampling event are shown on Figure 4-17.

Volatile Organic Compounds

Seventy-one samples from 10 intermediate-zone monitoring wells were collected during nine groundwater sampling events and analyzed for VOCs by USEPA Method 8260B. Four of the 71 groundwater samples were duplicate samples.

Chlorobenzene was detected in 41 of the 71 intermediate-zone groundwater samples at concentrations ranging from 2.5 μg/L (MWA-11i, 29 January 1999) to 140,000 μg/L (MWA-17si, 15 April 2002). Monitoring well MWA-11i is located in the Acid Plant Area, slightly upgradient from the former MPR pond. Monitoring well MWA-17si is located approximately 150 feet downgradient of the former MPR pond. The chlorobenzene concentration in the most recent sample collected from monitoring well MWA-17si (June 2003) was 73,200 μg/L, approximately one-half of the highest chlorobenzene concentration observed in that monitoring well.

Fourteen other VOCs were detected in samples collected from intermediate-zone groundwater monitoring wells. Concentrations of these constituents ranged from 0.5 to 530 μg/L, with most concentrations observed in the range of 0.5 to 10 μg/L.

A summary of analytical results for VOCs in monitoring well groundwater samples is provided in Table 4-26. Analytical results for chlorobenzene in intermediate-zone groundwater for the June 2003 sampling event are shown on Figure 4-18.

Semi-Volatile Organic Compounds

Fifty samples from nine intermediate-zone groundwater monitoring wells were collected during six groundwater sampling events and analyzed for SVOCs by USEPA Method 8270C or 8270-SIM. Five of the 50 samples were duplicate samples.

Thirty-three SVOCs were detected in 31 intermediate-zone groundwater samples. Of those 33 compounds, the most prevalent (in frequency and concentration) were: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3- and 4-chlorophenol, and benzoic acid. These constituents were detected at concentrations ranging from 0.2 to 180 μg/L, with the highest concentrations of these compounds observed in monitoring wells MWA-9i and MWA-17si. Other SVOCs were detected at relatively low concentrations that were generally at, or slightly greater than, method detection limits.

A summary of analytical results for SVOCs in monitoring well groundwater samples is provided in Table 4-27. Monitoring well locations are shown on Figure 2-4.

Petroleum Hydrocarbons

Two groundwater samples collected from monitoring well MWA-32i on 4 June 2003 were analyzed for diesel- and heavy oil-range petroleum hydrocarbons by USEPA Method NWTPH-Dx. One of the two samples was a duplicate sample. Diesel-range petroleum hydrocarbons were detected in both samples at concentrations of 0.342 and 0.32 mg/L. Heavy-oil range petroleum hydrocarbons were not detected in either sample.

A summary of analytical results for petroleum hydrocarbons in monitoring well groundwater samples is provided in Table 4-28. Monitoring well locations are shown on Figure 2-4.

Metals

Forty-four samples from 12 intermediate-zone monitoring wells were collected during five groundwater sampling events and analyzed for various metals by USEPA Methods 6010B or 6020. Three of the 44 intermediate-zone groundwater samples were duplicate samples.

Fifteen of the 44 samples were analyzed for total chromium. Chromium was detected in 12 of the 15 samples at concentrations ranging from 0.007 mg/L (MWA-16i, 25 August 1999) to 7 mg/L (MWA-31i, 7 March 2002). Monitoring well MWA-31i is located downgradient of the Chlorate Plant Area, adjacent to the salt pads in the southeastern corner of the Site. The most recent sample collected from monitoring well MWA-31i (June 2003) contained total chromium at a concentration of 1.15 mg/L.

One of the 15 intermediate-zone groundwater samples analyzed for chromium was also analyzed for total hexavalent chromium (MWA-16i, 25 August 1999). Hexavalent chromium was not detected in this sample above the method detection limit of 0.05 mg/L. The total chromium concentration in this sample was 0.007 mg/L.

Intermediate-zone groundwater samples were also analyzed for calcium, iron, magnesium, potassium, and sodium. Concentrations of these analytes were observed up to 303, 28.9, 110, 47.9, and 6,630 mg/L, respectively.

A summary of analytical results for metals in monitoring well groundwater samples is provided in Table 4-29. Analytical results for total chromium in intermediate-zone groundwater for the June 2003 sampling event are shown on Figure 4-19.

Perchlorate

Ten groundwater samples from 10 intermediate-zone monitoring wells were collected during the June and July 2003 groundwater sampling event, and were analyzed for perchlorate by USEPA Method 314.0. Perchlorate was detected in six of the 10 samples at concentrations ranging from 0.26 mg/L (MWA-10i, 10 June 2003) to 200 mg/L (MWA-32i, 4 June 2003). Monitoring well MWA-32i is located downgradient of the Chlorate Plant Area, adjacent to the salt pads in the southeastern corner of the Site.

A summary of analytical results for perchlorate in monitoring well groundwater samples is provided in Table 4-30. Analytical results for perchlorate in intermediate-zone groundwater for the most recent groundwater sampling event (June and July 2003) are shown on Figure 4-20.

Conventional Parameters and Miscellaneous Constituents

Groundwater samples collected from intermediate-zone monitoring wells were analyzed for a variety of conventional parameters and constituents, including: bicarbonate and carbonate alkalinity, total alkalinity, ammonia as nitrogen, sulfate, nitrate, nitrite, total organic carbon, chloral hydrate, p-chlorobenzenesulfonic acid (p-CBSA), total chloride, and dissolved methane. A total of 71 groundwater samples from 12 intermediate-zone monitoring wells were analyzed for some combination of the above parameters. Five of the 71 groundwater samples were duplicate samples.

Seventy intermediate-zone groundwater samples were analyzed for total chloride by USEPA Method 300.0. Total chloride concentrations in those samples ranged from 5 mg/L (MWA-28i, 9 April 2002) to 61,100 mg/L (MWA-31i, 4 June 2003). Monitoring well MWA-31i is located in the southeastern portion of the Site, between the salt pads and the Willamette River bank. The highest chloride concentrations in the intermediate-zone groundwater were observed in monitoring wells MWA-31i and MWA-32i. Both of these wells are located adjacent to the salt pads in the southeastern corner of the Site.

A summary of laboratory analytical results for conventional parameters and miscellaneous constituents is provided in Table 4-30. Analytical results for chloride in intermediate-zone groundwater for the June 2003 sampling event are shown on Figure 4-21.

4.2.2.3 *Deep-Zone Groundwater Analytical Results*

Total and Dissolved Organochlorine Pesticides

Nine samples from the deep-zone monitoring well MWA-13d were collected during eight groundwater sampling events and analyzed for total organochlorine pesticides by USEPA Method 8081A. Monitoring well MWA-13d is located approximately 150 feet downgradient of the Acid Plant Area. One of the nine groundwater samples was a duplicate sample. Total DDT was detected in seven of the nine samples at concentrations ranging from 0.065 μg/L (15 April 2002) to 0.43 μg/L (29 March 1999). Total DDD was also detected in seven of the nine groundwater samples at concentrations ranging from 0.05 μg/L (18 November 1999) to 0.091 μg/L (15 April 2002). No other pesticides were detected in groundwater samples collected from monitoring well MWA-13d.

Three samples from MWA-13d were collected during three groundwater sampling events and analyzed for dissolved organochlorine pesticides by USEPA Method 8081A. Dissolved pesticides were not detected in any of the deep-zone groundwater samples.

A summary of analytical results for total and dissolved organochlorine pesticides in monitoring well groundwater samples is provided in Table 4-25. Monitoring well locations are shown on Figure 2-4.

Volatile Organic Compounds

Nine samples from deep-zone monitoring well MWA-13d were collected during eight groundwater sampling events and analyzed for VOCs by USEPA Method 8260B. One of the nine groundwater samples was a duplicate sample. Chlorobenzene was detected in all nine deep-zone groundwater samples at concentrations ranging from 10.6 μg/L (9 June 2003) to 1,600 μg/L (25 August 1999 and 18 November 1999). The chlorobenzene concentration in the most recent sample collected from monitoring well MWA-13d (10.6 μg/L, June 2003) was approximately two orders of magnitude less than the mean chlorobenzene concentration in this well over time.

Three other VOCs were detected in four of the nine samples collected from the deep-zone groundwater monitoring well: 1,1-dichloroethane, 1,2-dichloroethane, and benzene. Concentrations of these constituents ranged from 0.6 to 3.5 μg/L.

A summary of analytical results for VOCs in monitoring well groundwater samples is provided in Table 4-26. Monitoring well locations are shown on Figure 2-4.

Semi-Volatile Organic Compounds

Six samples from monitoring well MWA-13d were collected during six groundwater sampling events and analyzed for SVOCs by USEPA Method 8270C or 8270-SIM. Six SVOCs were detected in four of the six deep-zone groundwater samples: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2-chlorophenol, 3- and 4-chlorophenol, dimethyl phthalate, and naphthalene. These constituents were detected at concentrations ranging from 0.1 to 6 μg/L.

A summary of analytical results for SVOCs in monitoring well groundwater samples is provided in Table 4-27. Monitoring well locations are shown on Figure 2-4.

Metals

Four samples from monitoring well MWA-13d were collected during four groundwater sampling events and analyzed for various metals by USEPA Method 6010B or 6020. Deep-zone groundwater samples were analyzed for calcium, iron, magnesium, potassium, and sodium. Concentrations of these analytes were observed up to 119, 4.37, 33.4, 47.9, and 2,450 mg/L, respectively.

A summary of analytical results for metals in monitoring well groundwater samples is provided in Table 4-29. Monitoring well locations are shown on Figure 2-4.

Perchlorate

One groundwater sample from deep-zone monitoring well MWA-13d was collected during the June 2003 groundwater sampling event, and was analyzed for perchlorate by USEPA Method 314.0. Perchlorate was not detected in this groundwater sample at or above the method detection limit of 0.020 mg/L.

A summary of analytical results for perchlorate in monitoring well groundwater samples is provided in Table 4-30. Monitoring well locations are shown on Figure 2-4.

Conventional Parameters and Miscellaneous Constituents

Nine groundwater samples collected from monitoring well MWA-13d were analyzed for a variety of conventional parameters and miscellaneous constituents, including: bicarbonate and carbonate alkalinity, total alkalinity, sulfate, nitrate, nitrite, total organic carbon, and total chloride. One of the nine groundwater samples was a duplicate sample.

All nine deep-zone groundwater samples were analyzed for total chloride by USEPA Method 300.0. Total chloride concentrations in those samples ranged from 2,100 mg/L (14 June 2001) to 3,360 mg/L (18 November 1999).

A summary of laboratory analytical results for conventional parameters and miscellaneous constituents is provided in Table 4-30. Monitoring well locations are shown on Figure 2-4.

4.2.2.4 *Basalt-Zone Groundwater Analytical Results*

Organochlorine Pesticides

Five samples from the basalt-zone monitoring well MWA-21b were collected during three groundwater sampling events and analyzed for total organochlorine pesticides by USEPA Method 8081A. Two of the five samples were duplicate samples. Monitoring well MWA-21b is located approximately 150 feet downgradient of the Acid Plant Area.

Total DDT was detected in all five samples at estimated concentrations ranging from 0.0074 μg/L (4 December 2001) to 0.022 μg/L (5 November 2001, duplicate sample). Total DDD was also detected in all five groundwater samples at concentrations ranging from 0.007 μg/L (5 November 2001) to 0.017 μg/L (5 November 2001, duplicate sample). No other organochlorine pesticides were detected in groundwater samples collected from monitoring well MWA-21b.

A summary of analytical results for total and dissolved organochlorine pesticides in monitoring well groundwater samples is provided in Table 4-25. Monitoring well locations are shown on Figure 2-4.

Volatile Organic Compounds

Five samples from basalt-zone monitoring well MWA-21b were collected during three groundwater sampling events and analyzed for VOCs by USEPA Method 8260B. Two of the five groundwater samples were duplicate samples. Chlorobenzene was detected in all five basalt-zone groundwater samples at concentrations ranging from 0.69 μg/L (12 April 2002) to 2.2 μg/L (4 December 2001, duplicate sample). The chlorobenzene concentration for the most recent sample collected from monitoring well MWA-21b (0.69 μg/L, April 2002) was approximately one-half of the mean chlorobenzene concentration in the four other samples collected from this well.

One other VOC, methylene chloride, was detected in one of the five samples collected from the basalt-zone groundwater monitoring well at a concentration of 1.3 μg/L (sample date 5 November 2001, duplicate sample).

A summary of analytical results for VOCs in monitoring well groundwater samples is provided in Table 4-26. Monitoring well locations are shown on Figure 2-4.

Conventional Parameters and Miscellaneous Constituents

One groundwater sample collected from monitoring well MWA-21b was analyzed for nitrate and nitrite by USEPA Methods 353.2 and 354.1, respectively. Nitrate and nitrite were not detected above the detection limits of 0.2 and 0.01 mg/L, respectively.

A summary of laboratory analytical results for conventional parameters and miscellaneous constituents is provided in Table 4-30. Monitoring well locations are shown on Figure 2-4.

4.3 STORM WATER SAMPLING RESULTS

Twelve storm water samples from two storm drain outfalls (SW-01 and SW-02) were collected during four sampling events and were analyzed for total and/or dissolved organochlorine pesticides by USEPA Method 8081A. Four of the 12 samples were duplicate samples.

Total DDT was detected in all 12 storm water samples at concentrations ranging from 0.28 μg/L (SW-02, 27 March 2001) to 47 μg/L (SW-01, 17 December 1999). In addition, total DDD was detected in 11 of the 12 storm water samples, and total DDE was detected in all 12 storm water samples.

Dissolved DDT was detected in the primary and duplicate samples collected from outfall SW-01 on 11 November 1999 at estimated concentrations of 0.4 and 0.3 μg/L, respectively. Additionally, dissolved DDT was detected in storm water samples collected from outfall SW-02 on 22 January 1999 and 11 November 1999, at estimated concentrations of 0.14 and 0.31 μg/L, respectively. No other pesticides were detected in any of the storm water samples.

A summary of laboratory analytical results for pesticides in storm water samples is provided in Table 4-31.

4.4 DENSE NON-AQUEOUS PHASE LIQUID INVESTIGATION

4.4.1 Phase I DNAPL Investigation

Compounds detected in the shallow-zone groundwater samples collected during the Phase I DNAPL investigation include chlorobenzene, chloroethane, chloroform, 1,4-dichlorobenzene, and tetrachloroethene (by USEPA Method 8260B). Detected chlorobenzene concentrations ranged from 35,500 to 502,000 μg/L, which corresponds to a range of 8 to 107 percent of the saturation limit based on the solubility of chlorobenzene (470,000 μg/L at 20 degrees Celsius). Residual DNAPL was observed in the form of small brown globules in groundwater samples collected from three Phase I DNAPL investigation borings. These visual observations of residual DNAPL were confirmed by Sudan IV dye testing.

The results of the Phase I DNAPL investigation indicate that the highest concentrations of chlorobenzene in shallow-zone groundwater occur immediately north and northeast of the former MPR pond, in a 5- to 6-foot thick zone directly above the shallow silt horizon. Dissolved chlorobenzene concentrations in this zone are indicative of saturated or near-saturated conditions. Results of both the Phase I and Phase II DNAPL Investigations are shown on Figures 4-22, 4-23, and 4-24. Analytical results and a more detailed discussion of the investigation results are presented in the *Residual Dense Non-Aqueous Phase Liquid Investigation (Phase I), Acid Plant Area* report (ERM 2002b).

4.4.2 Phase II DNAPL Investigation

Chlorobenzene was detected in the four groundwater samples collected at the bottom of the intermediate groundwater zone as part of the Phase II DNAPL investigation (by USEPA Method 8260B). One of the four groundwater samples was a duplicate sample. Detected chlorobenzene concentrations ranged from 80.9 μg/L (MIP-11, 41.0 to 46.0 feet bgs) to 61,600 μg/L (MIP-5, 41.0 to 44.0 feet bgs, duplicate sample). No other VOCs were detected in the intermediate-zone samples.

Residual DNAPL was detected at discrete depths in the shallow zone in each of the Phase II borings. The residual DNAPL was detected within a 6-foot zone directly above the first significant silt layer of the shallow-zone silt horizon. Residual DNAPL was also detected at intermediate-zone elevations in one boring located near the middle of the former MPR pond (boring INT-5). Residual DNAPL was detected in this boring at a depth of approximately 38 feet bgs, directly above a 1-foot thick silt lens at 39 feet bgs (Figure 4-23). It is possible that this silt lens is associated with the silt layer situated between the shallow and intermediate groundwater zones and therefore DNAPL is only present in the shallow groundwater zone. Residual DNAPL was detected in shallow-zone soils in this boring at approximately 26, 29, and 33 feet bgs. Residual DNAPL was not detected in the intermediate groundwater zone in the other six Phase II DNAPL investigation borings.

Analytical results and a more detailed discussion of the findings of the Phase II investigation are presented in the *Phase II Residual Dense Non-Aqueous Phase Liquid Investigation (Intermediate-Zone Sampling), Acid Plant Area* report (ERM 2002d).

4.5 BPA MAIN SUBSTATION SOIL SAMPLING

Sixty-four of the 72 soil samples collected by BPA within the Pennwalt Substation during the Phase II ESA (November 2001) were analyzed for PCBs by USEPA Method 8082. PCBs were detected in nine of the 64 samples at concentrations ranging from 0.166 to 1.25 mg/kg (total of seven Arochlor compounds). In addition to PCBs, the following constituents were detected in the Phase II ESA:

- TPH in seven samples at concentrations ranging from 141 to 8,550 mg/kg (combined total of diesel- and heavy oil-range hydrocarbons);
- Seven PAH compounds in one sample at concentrations ranging from 0.05 to 0.171 mg/kg;
- Lead in one sample at a concentration of 543 mg/kg; and
- DDT and DDE in one sample at concentrations of 0.056 and 0.009 mg/kg, respectively.

No VOCs (chlorobenzene, 1,1,1-trichloroethane, or BTEX) were detected in any of the samples (PBS 2002). Soil sample locations in the BPA substation are shown on Figure 2-7.

None of the eight additional soil samples collected by BPA in March 2002, which included the storm water drainage swales, contained PCBs above the method detection limit of 0.05 mg/kg.

After BPA removed its electrical equipment, ATOFINA Chemicals collected 37 soil samples from within the substation (June 2002). PCBs were detected in 11 of the 37 samples at concentrations ranging from 0.13 mg/kg to 8.5 mg/kg (sample number BPA-20). Based on these results, BPA conducted soil removal in the northwestern portion of the substation (Figure 2-7). Composite confirmation samples from the excavation sidewalls revealed PCBs concentrations ranging from 2.4 to 4.5 mg/kg (surface samples), 0.16 to 2.7 mg/kg (1.5 feet bgs), and 0.15 to 3.1 mg/kg (3 feet bgs).

In addition to the soil excavation and confirmation sampling, eight discrete soil samples were collected between the substation and Front Avenue in October 2002. Concentrations of PCBs in these eight samples ranged from non-detect (<0.15 mg/kg) to 0.91 mg/kg.

Analytical results of PCBs in soil samples collected from within and adjacent to the BPA substation are shown on Figure 4-25.

5.0 EXTENT OF CONTAMINATION AND CONCEPTUAL SITE MODEL

5.1 CONSTITUENTS OF INTEREST

The primary COIs in upland soil that will be evaluated in the Baseline Risk Assessment consist of:

- DDT and its metabolites, DDD and DDE;
- Chlorobenzene; and
- Hexavalent chromium.

A complete list of COIs in soil that will be evaluated in the Baseline Risk Assessment is provided in Table 5-1.

The primary COIs in upland groundwater that will be evaluated in the Baseline Risk Assessment consist of:

- DDT and its metabolites, DDD and DDE;
- Chlorobenzene;
- Hexavalent chromium; and
- Perchlorate.

A complete list of COIs in groundwater that will be evaluated in the Baseline Risk Assessment is provided in Table 5-1.

5.2 SOURCE AREAS

Source areas have been identified based on the relationship between likely source areas identified in the Preliminary Assessment and the distribution of COIs in Site soils and groundwater as assessed during the RI. The following areas are considered to be on-site source areas:

- Acid Plant Area;
- Chlorate Plant Area; and

- Salt Pads.

5.2.1 *Acid Plant Area*

The Acid Plant Area consists of the former MPR pond, trench, and the MCB recovery unit. Historically, the MPR pond and trench received DDT manufacturing process wastes from initial plant operations (1947) up until approximately 1954.

5.2.1.1 *Acid Plant Area Soil*

DDT and chlorobenzene have been detected in soil at concentrations up to 16,000 mg/kg (boring B-53, 4.5 to 6 feet bgs) and 8,800 mg/kg (boring IB-21, composite of zero to 10 feet bgs), respectively, in and around the former MPR pond. Figures 4-1 and 4-2 show the lateral extent of DDT, DDD, and DDE in Acid Plant Area soils from zero to 3 feet bgs and from 3 feet to the maximum depth sampled, respectively, for soil sampling borings. Figures 4-7 and 4-8 show the lateral extent of DDT and its metabolites in the same depth intervals for IRM borings. Figures 4-3 and 4-4 show the lateral extent of chlorobenzene in Acid Plant Area soils from zero to 3 feet bgs and from 3 feet to the maximum depth sampled, respectively, for soil sampling borings. Figure 4-9 shows analytical results for chlorobenzene in soil samples collected from IRM and VES borings. A total of approximately 4,715 tons of DDT- and chlorobenzene-contaminated soil exhibiting the highest constituent concentrations were removed from the Acid Plant Area through implementation of IRMs. Additionally, other areas where DDT and chlorobenzene were observed were addressed by installation of temporary cover or asphalt paving to prevent transport of constituents via storm water runoff and erosion of surface soils. IRMs are described in Section 6.0.

5.2.1.2 *Acid Plant Area Groundwater*

The highest concentration of DDT in shallow-zone groundwater measured during the most recent groundwater sampling event (June 2003) was observed at monitoring well MWA-15r at a concentration of 113 μg/L. DDT was detected in intermediate-zone groundwater during the June 2003 groundwater sampling event in monitoring well MWA-11i at a concentration of 0.573 μg/L. However, this result was flagged with a "U" qualifier based on the data validation review. Figures 4-12 and 4-17 show DDT concentrations observed during the June 2003 sampling event in shallow- and intermediate-zone groundwater, respectively. DDT concentrations are shown on cross sections A-A′ and B-B′ on Figures 5-1 and 5-2, respectively (see Figure 3-1 – Cross Section Location Map).

The highest concentrations of chlorobenzene in shallow- and intermediate-zone groundwater measured during the most recent groundwater sampling event (June 2003) were observed in the Acid Plant Area at monitoring wells MWA-2 and MWA-17si at concentrations of 13,700 and 73,200 μg/L, respectively. Figures 4-13 and 4-18 show the extent of chlorobenzene in shallow- and intermediate-zone groundwater, respectively, for the June 2003 sampling event. Chlorobenzene concentrations are shown on cross sections A-A′ and B-B′ on Figures 5-3 and 5-4, respectively (see Figure 3-1).

Other areas of the Site outside the Acid Plant Area where DDT and/or chlorobenzene have been detected are not considered source areas because the locations of the detections are not associated with historical use of these constituents, and the detected concentrations are relatively low.

In addition to DDT manufacturing operations, ammonium perchlorate operations were conducted in the former DDT process building from 1958 until 1962. The Acid Plant Area is considered a source area of perchlorate. Although perchlorate was detected in groundwater downgradient of the Acid Plant Area, significantly higher perchlorate concentrations were observed in groundwater downgradient of the Chlorate Plant Area.

5.2.1.3 DNAPL in the Acid Plant Area

The DNAPL Investigations identified residual chlorobenzene DNAPL in groundwater in the Acid Plant Area. DNAPL was primarily observed either on top of or within a 6-foot zone directly above the low-permeability silt horizon at the base of the shallow zone. DNAPL was also detected at intermediate-zone elevations in one boring (boring INT-5). Results of the DNAPL Investigations are shown on Figures 4-22, 4-23, and 4-24.

5.2.2 Chlorate Plant Area

The Chlorate Plant Area consists of the Chlorate Cell Room, Chlorate Process Building, Chlorate Warehouse, and other associated buildings.

The Preliminary Assessment identified the Chlorate Plant Area as a potential source area for chromium. Historical releases of sodium bichromate in this area have resulted in the presence of hexavalent chromium (Cr[VI]) in soil and groundwater.

5.2.2.1 *Chlorate Plant Area Soil*

Chromium has been detected in soil in the Chlorate Plant Area at concentrations up to 1,600 mg/kg (boring B-88, 10 to 12 feet bgs). Hexavalent chromium has been detected in soil at concentrations up to 69 mg/kg (boring B-77, 8 to 10 feet bgs). Figures 4-5 and 4-6 show total and hexavalent chromium concentrations in soil for depth intervals of zero to 4 feet bgs and 4 feet to the maximum depth sampled, respectively.

5.2.2.2 *Chlorate Plant Groundwater*

Chromium has been detected in groundwater in the Chlorate Plant Area in shallow- and intermediate-zone groundwater at concentrations up to 9.79 and 1.15 mg/L, respectively (monitoring wells MWA-25 and MWA-31i). Hexavalent chromium had been detected at concentrations of 0.058 mg/L (monitoring well MWA-6r, 25 August 1999) and 0.060 mg/L (monitoring well MWA-20, 13 June 2001). Figures 4-14 and 4-19 show chromium concentrations in shallow- and intermediate-zone groundwater, respectively, for the most recent groundwater sampling event (June 2003). Chromium concentrations are shown on cross sections A-A′, C-C′, and D-D′ on Figures 5-5, 5-6, and 5-7, respectively (see Figure 3-1 for the cross section location map).

In addition to the chromium detections in soil and groundwater, perchlorate was detected in groundwater downgradient of the Chlorate Plant Area at concentrations up to 290 and 200 mg/L in shallow- and intermediate-zone groundwater wells, respectively (MWA-25 and MWA-32i). Figures 4-15 and 4-20 show perchlorate concentrations in shallow- and intermediate-zone groundwater, respectively, for the June and July 2003 sampling event. Perchlorate concentrations are shown on cross sections A-A′, C-C′, and D-D′ on Figures 5-8, 5-9, and 5-10, respectively (see Figure 3-1 for the cross section location map).

Other areas of the Site where chromium and perchlorate have been detected are not considered source areas because the locations of the detections are not associated with historical use of these constituents, and/or the detected concentrations are relatively low.

5.2.3 *Salt Pads*

Historically, sea salt (NaCl) was used as a raw material for products manufactured at the Site. The salt pads were used to store salt and produce brine for use in site manufacturing operations. Salt piles were stored on the Salt Pads and a brine solution was created by sprinkling the salt with water.

Chloride has been detected in all groundwater monitoring wells at the Site. The Salt Pads are the primary source area for chloride, based on the relatively higher concentrations observed and historical brine production operations in this area. Other areas where chloride has been detected are not considered source areas because of the ubiquitous nature of chloride (i.e., background concentrations), the locations of the detections are not associated with historical use of chloride-containing materials, and concentrations are relatively low. Figures 4-16 and 4-21 show the chloride concentrations for the shallow and intermediate groundwater zones, respectively, for the June 2003 groundwater sampling event.

5.3 *POTENTIAL TRANSPORT PATHWAYS*

Various potential transport pathways have influenced the movement of COIs from source areas to where they are presently found in soil and groundwater. Potential historical pathways include:

- Infiltration;
- Groundwater migration via advection and hydrodynamic dispersion;
- DNAPL migration;
- Surface water discharge (overland flow);
- Storm water discharge (pipeline); and
- Air transport (vapors, particulates, dust).

In order to determine whether the storm drain system acts as a conduit for constituents in groundwater, storm drain system manhole elevations were compared to groundwater elevations in monitoring wells nearest to the manholes. Invert elevations at 11 manholes in the Acid Plant and Chlorate Plant Areas were compared to minimum and maximum groundwater depths observed over the duration of the RI. Figure 5-11 shows the location of the storm drain system manholes. Table 5-2 presents the results of the comparison. Based on the comparison, it has been determined that storm drain system invert elevations are uniformly above groundwater in both the Acid Plant and Chlorate Plant Areas. Therefore, the storm drain system is not a potential transport pathway for COIs in groundwater.

5.4 CHEMICAL PROPERTIES AND PERSISTENCE OF CONSTITUENTS OF INTEREST

Chemical properties of the primary COIs are discussed in this section. An understanding of these properties is helpful for understanding the relationship between the source area distribution and the potential transport mechanisms for COIs in the environment. Chemical properties of the primary COIs are summarized in Table 5-3.

5.4.1 DDT, DDD, and DDE

DDT and its metabolites are organochlorine pesticides that are solid at ambient temperatures and have low aqueous solubilities and low volatilities. In aqueous solutions, DDT readily partitions to the solid or organic carbon phases in the matrix. DDT is, consequently, persistent in soils and generally found in groundwater at concentrations less than 1 µg/L, when present. However, DDT is highly soluble in organic liquids and has a reported solubility in chlorobenzene of 740,000 mg/L (Sconce 1962). The mobilization of a water-insoluble chemical like DDT in a soluble and mobile chemical such as chlorobenzene is termed cosolvency. Cosolvency is the likely reason for the observed DDT concentrations in groundwater at the Site. DDT can be degraded by both aerobic and anaerobic pathways, although extensive dechlorination of DDT is usually observed under anaerobic conditions.

5.4.2 Chlorobenzene

Chlorobenzene is a volatile organic liquid at ambient temperatures. Chlorobenzene has a moderately high aqueous solubility and is highly volatile. Chlorobenzene does not readily partition to soil particles or solid organic carbon phases and is, therefore, mobile in aqueous solutions. Liquid chlorobenzene has a higher density (specific gravity of 1.106) and a lower viscosity than water (absolute viscosity of 0.80 centipoise). Therefore, non-aqueous phase liquid chlorobenzene migrates relatively easily downward through groundwater. Chlorobenzene degradation occurs by an aerobic pathway. The rate of degradation is highly dependent of the acclimatization of degrading microorganisms.

5.4.3 *Hexavalent Chromium*

Hexavalent chromium (Cr[VI]) compounds are widely used in process manufacturing and production. Hexavalent chromium usually exists as a highly stable anion (i.e., dichromate [$Cr_2O_7^{2-}$] or chromate [CrO_4^{2-}]). Another common form of chromium is trivalent chromium (Cr[III]). Trivalent chromium exists as a cation and is generally insoluble at a pH above 5-6. Trivalent chromium typically will precipitate as a chromic hydroxide, $Cr(OH)_3$, in an alkaline environment. Hexavalent chromium is more soluble and toxic than trivalent chromium. Typically, the most effective remediation or control strategy for hexavalent chromium is to reduce it to trivalent chromium using a reducing agent.

5.4.4 *Perchlorate*

Perchlorates are chemical compounds that contain the monovalent ClO_4^- radical (perchlorate anion). Perchlorate is generated by the dissolution of ammonium, potassium, magnesium, or sodium salts. Ammonium perchlorate (NH_4ClO_4) was produced using sodium perchlorate ($NaClO_4$) at the facility. Perchlorates are crystalline solids at room temperature. Behavior of the perchlorate anion is controlled by its basic chemical properties. As an oxidant, the reduction of the chlorine atom occurs slowly. Perchlorate is very soluble in water and does not interact with the soil matrix in the aquifer. In addition, the half-life of perchlorate in the environment seems to be very long. Therefore, perchlorate travels at close to the speed of the groundwater. Bioremediation appears to be an effective treatment technology for reducing perchlorate mass and concentration in groundwater.

5.5 *POTENTIAL RECEPTORS*

The following have been identified as potential receptors of Site COIs:

- Site workers;
- Site construction workers;
- Site trench/excavation/utility workers;
- Trespassers;
- Willamette River human receptors (recreation); and
- Willamette River ecological receptors.

The human health and ecological risk assessments for the Site will further discuss potential receptors.

6.0 SUMMARY OF INTERIM REMEDIAL ACTIONS

Concurrent with implementation of the RI, various IRMs were conducted at the Site. Remedial activities included the following:

- Performance of a two-phase soil removal IRM;
- Installation and operation of a soil VES; and
- Performance of three remediation pilot studies and a bench-scale remediation study.

The following sections describe these interim remedial activities.

6.1 SOIL REMOVAL INTERIM REMEDIAL MEASURES

During the implementation of RI field activities, evidence of DDT- and chlorobenzene-contaminated soil was observed in the Acid Plant Area. Soils containing elevated concentrations of DDT and chlorobenzene were observed within the former MPR pond and trench (Area A), in an unpaved area approximately 150 feet west of the MPR pond and trench (in the vicinity of soil boring B-49; Area B), in the unpaved area immediately north of the Acid Plant (Area C), and in the area north of the former MCB Recovery Unit Area and south of No. 2 Warehouse (Area D). Figure 6-1 shows the approximate extent of these areas. Elevated DDT and chlorobenzene concentrations were primarily identified from near ground surface to approximately 8 feet bgs. DDT and chlorobenzene were observed up to 22 feet bgs in the immediate vicinity of the former Acid Plant (boring B-61).

In response to these elevated DDT and chlorobenzene concentrations, ATOFINA Chemicals implemented a two-phased IRM to mitigate potential environmental impacts. The purpose of the IRM was to:

- Remove DDT-contaminated soil in Areas A, B, C, and D to the extent technically practical;
- Construct site drainage improvements to ensure proper drainage and reduce ponding of surface water; and

- Construct limited paving and a temporary surface cover to minimize contamination resulting from storm water runoff and erosion of surface soils.

The IRM targeted DDT concentrations greater than 1,200 mg/kg. The DDT comparison value of 1,200 mg/kg was derived from the USEPA Region IX preliminary remediation goal (PRG) for DDT using a 1-in-10,000 cancer risk. This value, while equivalent to the ODEQ's default "hot spot" criteria for DDT, was used only as a screening value to identify which surface or near-surface soil might need to be addressed by the IRM.

IRM activities were carried out in two phases. Excavation and construction activities were carried out in accordance with the *Interim Remedial Measures Work Plan* (Exponent 2000), approved by ODEQ on 20 September 2000, and the *Phase II Soil Interim Remedial Measure Workplan* (ERM 2001a), approved by ODEQ in a letter dated 18 October 2001.

The Phase I soil removal IRM was performed at the Site between September and November 2000. Phase I focused on the former DDT MPR pond and trench areas (Area A, Figure 6-1) and the areas surrounding borings B-49 and SB-05 (Areas B and C, Figure 6-1). The scope of the Phase I IRM included:

- Excavation and disposal of DDT-contaminated soil;
- Grading, paving, and storm water conveyance improvements; and
- Construction of a temporary surface cover system over certain areas to minimize potential contamination from storm water runoff.

Excavations were conducted to depths of approximately 12, 2.5, and 1 foot in Areas A, B, and C, respectively. A total of approximately 3,800 tons of soil was excavated and removed as part of the Phase I soil IRM. Additionally, a temporary surface cover was constructed in the unpaved area east of the Acid Plant Area, where unpaved soil samples had been collected. The temporary surface cover consisted of a layer of visqueen plastic between two geotextiles, buried beneath approximately 2 inches of ¾-inch-minus gravel. Further details regarding the Phase I soil IRM activities are presented in the *Interim Remedial Measures Implementation Report*, dated 26 February 2001 (ERM 2001c).

The Phase II soil removal IRM was carried out between 5 and 16 November 2001. Phase II focused on the area north of the former Acid Plant Area and south of No. 2 Warehouse (Area D, Figure 6-1), where sampling had revealed elevated DDT concentrations in soil. The scope of the Phase II soil IRM included:

- Excavation of soil up to 1 foot bgs over the entire Area D and to 7 feet bgs in the vicinity of soil boring B-61;
- Limited paving in the former Acid Plant Area and Area D to minimize the potential for contamination from storm water runoff; and
- Installation of a storm drain and associated piping west of the former Acid Plant Control House to collect storm water runoff.

A total of 915 tons of contaminated soil was removed from Area D as part of the Phase II soil IRM. A detailed description of the Phase II soil IRM activities is presented in the *Phase II Soil Interim Remedial Measure Final Report*, dated February 2002 (ERM 2002e).

The Phase I and II IRMs were effective in removing significant quantities of soil containing DDT and chlorobenzene and reduced the potential for transport of constituents in shallow soils.

6.2 MCB RECOVERY UNIT AREA SOIL VAPOR EXTRACTION SYSTEM

The Phase I and II soil IRMs were conducted to remove DDT-contaminated soils in and around the Acid Plant Area. However, no soil removal was conducted in the former MCB Recovery Unit Area due to high concentrations of chlorobenzene in shallow soil. A soil VES was installed in December 2000 to extract chlorobenzene mass from subsurface soils, thereby reducing chlorobenzene concentrations to allow disposal of the soil as a non-hazardous waste following future excavation activities. The preliminary remedial goal for chlorobenzene was 2,000 mg/kg (20 times hazardous waste toxicity characteristic of 100 mg/L). The system was expanded incrementally over the 2-1/2 years of operation and ultimately included 5 horizontal extraction wells. The system was installed, operated, and monitored in accordance with the *Workplan for Full-Scale Vapor Extraction System* (ERM 2000) and subsequent work plan addenda approved by ODEQ. The locations of VES extraction wells are shown on Figure 2-3.

Over the duration of VES operation, eight hand-auger borings were drilled and 24 direct-push vapor monitoring points were installed to provide soil characterization in the former MCB Recovery Unit Area and to monitor effectiveness of the VES. Analytical results for soil samples collected from these borings are presented in Section 4.0. In addition to the vapor monitoring points, 15 confirmation soil borings (CS-1 through CS-15, Figure 2-3) were drilled in the VES area to evaluate the effectiveness of the VES and to provide data to guide potential future operation of the VES and/or future soil excavation. The confirmation borings were drilled on 8 April 2003.

Analytical results from 10 of the 15 soil samples collected from confirmation borings revealed detections of chlorobenzene greater than the remedial action goal (2,000 mg/kg). Chlorobenzene concentrations ranged from 0.270 to 66,000 mg/kg. The confirmation sampling results revealed chlorobenzene concentrations in soil greater than had been previously observed in the former MCB Recovery Unit Area. Generally, samples with higher chlorobenzene concentrations than those previously observed were located around the VES extraction wells. Additionally, non-aqueous phase liquid chlorobenzene was observed at one of the confirmation borings.

Detailed descriptions of the VES installation, operation, and monitoring, including analytical summary tables and laboratory analytical reports are presented in monthly progress reports and the *Confirmation Soil Sampling Summary Report*, dated 26 August 2003 (ERM 2003b).

6.3 PILOT STUDIES

Three remedial pilot studies have been carried out at the facility as source control measures, to address:

- Elevated chlorobenzene concentrations in groundwater in the Acid Plant Area (*In-Situ Sodium Persulfate Pilot Study Work Plan*, [ERM 2001d]);
- The presence of DNAPL in the Acid Plant Area (*DNAPL Pilot Study Work Plan*, [ERM 2003c]); and
- Chromium in groundwater downgradient of the Chlorate Cell Room (*Hexavalent Chromium Pilot Study Work Plan*, [ERM 2003d]).

In addition to the pilot studies carried out at the facility, a bench-scale study has been initiated to evaluate the effectiveness of in-site anaerobic bioremediation to treat perchlorate in groundwater at the Site (*Scope of Work for Bench-Scale Testing of In-Situ Bioremediation to Treat Perchlorate in Groundwater at the ATOFINA Chemicals, Inc. Facility in Portland, Oregon*, [ATOFINA Chemicals 2003b]). A secondary goal of the study is to assess the fate of hexavalent chromium as a result of perchlorate biotreatement.

The pilot and bench-scale studies are mentioned here for completeness in describing environmental work performed at the facility. The scope, implementation, results, and conclusions of these studies will be discussed in detail in the FS prepared for the Site.

7.0 LAND AND BENEFICIAL WATER USE

The following sections discuss current and reasonably anticipated land uses, and current and reasonably likely future beneficial uses of groundwater in the locality of facility (LOF). The results will support efforts to identify and evaluate exposure pathways, assess risks, and select a preferred remedial alternative.

7.1 LOCALITY OF FACILITY

According to OAR 340-122-115(35):

> "'Locality of the facility' means any point where a human or an ecological receptor contacts, or is reasonably likely to come into contact with, facility-related hazardous substances, considering:
>
> (a) The chemical and physical characteristics of the hazardous substances;
>
> (b) Physical, meteorological, hydrogeological, and ecological characteristics that govern the tendency for hazardous substances to migrate through environmental media or to move and accumulate through food webs;
>
> (c) Any human activities and biological processes that govern the tendency for hazardous substances to move into and through environmental media or to move and accumulate through food webs; and
>
> (d) The time required for contaminant migration to occur based on the factors described in (a) through (c)."

For the purposes of the upland investigation and this report, the LOF is assumed to be the ATOFINA Chemicals facility and the riverbank to the mean high Willamette River water level.

7.2 *CURRENT AND FUTURE LAND USE*

This section describes the current and reasonably anticipated future land use in the LOF in accordance with OAR 340-122-0080(3)(e) and *Consideration of Land Use in Environmental Remedial Actions* (ODEQ 1998b). According to this guidance, in selecting a remedial action, the following must be taken into account:

- Current land uses;
- Zoning, comprehensive plan, or other land use designations;
- Land use regulations from any governmental body having jurisdiction;
- Concerns of the facility owner, the neighboring owners, and the community; and
- Other relevant factors.

The current and reasonably likely future land use in the locality of facility is well defined. The Site is located in the heart of the Guild's Lake Industrial Sanctuary, zoned and designated "IH" for heavy industrial use. On 14 December 2001, the Portland City Council voted to adopt the Guild's Lake Industrial Sanctuary Plan ([GLISP], City of Portland 2001). The plan is intended to preserve industrial land in the area generally bounded by Vaughn Street on the south, the St. Johns Bridge on the north, Highway 30 on the west, and the Willamette River on the east. The plan became effective on 21 December 2001.

The purpose of the GLISP is to maintain and protect this area as a dedicated place for heavy and general industrial uses. The plan's vision statement, policies, and objectives were adopted as part of Portland's Comprehensive Plan and are implemented through amendments to the City's Zoning Code. As a result of the GLISP, future land use in the LOF will be industrial.

7.3 *BENEFICIAL WATER USE*

Information regarding use of water potentially affected by former manufacturing operations had been collected as part of the Phase 2 Site Characterization (CH2M Hill 1997) and a beneficial water use survey conducted for a nearby facility (Woodward-Clyde 1997). Based on the findings of these studies and other available information for the facility, no current direct beneficial uses of groundwater (e.g., domestic water use) have been identified. Potential beneficial uses of nearby surface water (the Willamette River) include industrial use, recreational use, and ecological habitat in the LOF.

Previous site development efforts by ATOFINA Chemicals also support the finding of no direct beneficial water uses for groundwater in the LOF. Specifically, in the 1940s and 1950s, Pennwalt tried to develop site groundwater for industrial use by installing wells on the site. The aquifer beneath the site (to depths of more than 700 feet) was found to provide insufficient yield for industrial use and was found to have insufficient quality for the planned industrial purposes due to elevated salinity. These findings support the exclusion of industrial and landscape irrigation as beneficial uses for groundwater in the LOF.

No drinking water wells are located on or near the LOF. Groundwater is not currently used nor is it reasonably likely to be used in the future as a drinking water source. Because of the proximity of the Site to the Willamette River, future industrial water needs (e.g., non-contact cooling water) are likely to be met by surface water or by the City of Portland municipal water supply. The beneficial use for groundwater in the LOF is expected to be surface water recharge to the Willamette River. The potential impacts from the upland area and associated groundwater on the adjacent river environment will be examined as part of the Baseline Risk Assessment conducted for the Site and through source control measures implemented as part of the FS.

8.0 HOT SPOT EVALUATION

The ODEQ regulations require that certain actions be taken for "hot spots" of contamination. These actions are: (1) the identification of hot spots as part of the RI/FS, and (2) the treatment of hot spots, to the extent feasible, as part of a remedial action selected or approved by the Director of ODEQ (ODEQ 1998c).

The definition of hot spots is dependent on the medium that is contaminated. Generally, for water, a hot spot exists if contamination results in a significant adverse effect on the beneficial use of that resource and if restoration or protection of the beneficial use can occur within a reasonable amount of time. For media other than water (e.g., soil), a hot spot exists if the site presents an unacceptable risk and if the contamination is highly concentrated, highly mobile, or cannot be reliably contained (ODEQ 1998c).

According to ODEQ guidance, the following information is used to identify hot spots throughout the RI/FS process:

- Delineation of the nature and extent of contamination;
- Identification of current and reasonably likely future land use(s) and beneficial use(s) of water;
- Identification of significant contaminant migration routes and exposure pathways; and
- Evaluation of the protectiveness and feasibility of various remedial action alternatives (ODEQ 1998c).

8.1 GROUNDWATER AND SURFACE WATER

The Oregon Environmental Cleanup Rules define hot spots in groundwater and surface water as:

> *OAR 340-122-115(31)(a): For groundwater or surface water, hazardous substances having a significant adverse effect on beneficial uses of water or waters to which the hazardous substances would be reasonably likely to migrate and for which treatment is reasonably likely to restore or protect*

such beneficial uses within a reasonable time, as determined in a feasibility study.

As discussed in Section 7.3, the beneficial use of groundwater in the LOF is assumed to be surface water recharge to the Willamette River. The potential beneficial uses of nearby surface water (the Willamette River) include industrial use, recreational use, and ecological habitat in the LOF.

The State of Oregon has derived pre-calculated hot spot levels for use in identifying areas of contamination having a "significant adverse effect" on groundwater or surface water used for drinking water (the hot spot "look-up tables;" ODEQ 1998d). Because these pre-calculated hot spot levels assume a beneficial water use of drinking water, which is not the case at the Site, the levels are not applicable to the Site. Preliminary, site-specific hot spot levels for groundwater will be derived in the Baseline Risk Assessment. The Baseline Risk Assessment will be prepared and submitted as a separate report. Potential hot spots identified in the Baseline Risk Assessment will be further evaluated in the FS.

8.2 MEDIA OTHER THAN WATER

The Oregon Environmental Cleanup Rules define hot spots in media other than water as:

> *OAR 340-122-115(31)(b): For media other than groundwater or surface water (e.g., contaminated soil, debris, sediments, and sludges; drummed waste; 'pools' of dense, non-aqueous phase liquids submerged beneath groundwater or in fractured bedrock; and non-aqueous phase liquids floating on groundwater), if hazardous substances present a risk to human health or the environment exceeding the acceptable risk level, the extent to which the hazardous substances:*
>
> *(A) Are present in concentrations exceeding risk-based concentrations corresponding to:*
>
> *(i) 100 times the acceptable risk level for human exposure to each individual carcinogen;*
>
> *(ii) 10 times the acceptable risk level for human exposure to each individual non-carcinogen;*

(iii) 10 times the acceptable risk level for individual ecological receptors or populations of ecological receptors to each individual hazardous substance;

(B) Are reasonably likely to migrate to such an extent that the conditions specified in subsection (a) or paragraphs (b)(A) or (b)(C) would be created; or

(C) Are not reliably containable, as determined in the feasibility study.

According to ODEQ guidance, assessing a site for hot spots in media other than water first requires an evaluation of the site's baseline risk. Preliminary, site-specific hot spot levels for soil will be derived in the Baseline Risk Assessment. Potential hot spots identified in the Baseline Risk Assessment will be further evaluated in the FS.

9.0 SUMMARY OF REMEDIAL INVESTIGATION FINDINGS AND CONCLUSION

The results of the RI sampling and analysis, based on data collected to date, are summarized below by medium (soil, groundwater, and storm water).

9.1 SUMMARY OF REMEDIAL INVESTIGATION FINDINGS

9.1.1 Soil

Soil samples were collected from soil sampling borings, IRM borings, VES borings, monitoring well borings, surface sample locations, and riverbank sample locations during the RI.

9.1.1.1 Acid Plant Area

Samples collected from locations in the Acid Plant Area indicate that COIs are present in soil at depths of up to 32 feet bgs.

DDT was observed in soil samples at concentrations of up to 16,000 mg/kg (boring B-53, 4.5 to 6 feet bgs) in the former MPR pond. In general, DDT concentrations are greatest in shallow soils (up to 1 to 2 feet bgs) and decrease with depth. Soil in the vicinity of the two borings in which the highest DDT concentrations were observed and the majority of shallow soil containing DDT was removed during the soil removal IRMs. Several of the sample locations where elevated DDT concentrations were detected are beneath existing concrete building foundation slabs.

Chlorobenzene was observed locally at low concentrations in shallow soil (zero to 3 feet bgs) in the Acid Plant Area. Concentrations of chlorobenzene up to 0.021 mg/kg were observed in borings B-100 and B-101. These borings were advanced within the footprint of the DDT process building. Chlorobenzene was also observed in soil deeper than 3 feet bgs, over a slightly larger area than in shallow soil. Concentrations up to 8,800 mg/kg were detected in soil sampling borings, IRM borings, and VES borings in the vicinity of the former MCB recovery unit area. The highest chlorobenzene concentrations and a majority of the chlorobenzene mass were observed just above the silt layer situated at approximately 7.5 to 8 feet bgs. Although some chlorobenzene-impacted soil was removed during the IRMs, chlorobenzene-impacted soil remains on site in the Acid Plant Area at depths up to 14 feet bgs.

9.1.1.2 *Chlorate Plant Area*

Concentrations of chromium were observed in soil in the Chlorate Plant Area, at concentrations up to 180 mg/kg from zero to 4 feet bgs, and up to 1,600 mg/kg from 4 feet to approximately 32 feet bgs. The highest concentrations of chromium in soil are found in the immediate vicinity of the Chlorate Cell Room. Chromium concentrations decrease to typical background soil concentrations (i.e., 42 mg/kg; DEQ 2002a) within approximately 250 feet of the Chlorate Cell Room.

Soil samples have not been collected for analysis of perchlorate within the Chlorate Plant Area.

9.1.1.3 *BPA Main Substation*

Polychlorinated biphenyls were detected in soil during a Phase II ESA conducted by BPA in the BPA Main Substation (referred to as the Pennwalt Substation, PBS 2002). PCBs were detected in shallow soil (zero to 5 feet bgs) at concentrations up to 1.25 mg/kg (total of seven Aroclor compounds). In addition to PCBs, TPH, seven PAHs, lead, DDT, and DDD were detected at low concentrations in soil samples collected in the substation area (PBS 2002).

Soil samples collected in storm water drainage swales north and south of the substation did not contain PCBs above the detection limit of 0.05 mg/kg. Excavation of soil in the northwestern corner of the former substation removed soil containing the highest observed concentrations of PCBs. Confirmation samples indicate that soil containing PCBs at concentrations up to 4.5 mg/kg remain on site, within the former substation. Samples collected in the area between the substation and NW Front Avenue indicate that PCB concentrations in soil are less than 0.91 mg/kg. Based on these results, PCBs are included in the list of COIs for evaluation in the Baseline Risk Assessment.

9.1.2 *Groundwater*

In general, groundwater at the Site flows towards the Willamette River. The inferred groundwater flow direction is generally east to northeast in the Acid Plant Area, and east to southeast in the Chlorate Plant Area. Three groundwater zones, designated as the shallow, intermediate, and deep zones, have been identified at the Site. These zones are separated by thinner, lower permeability layers with higher silt content. The three groundwater zones are underlain by water-bearing basalt bedrock, referred to the basalt zone.

Groundwater quality at the Site was characterized by collecting and analyzing groundwater samples from both soil borings and monitoring wells.

9.1.2.1 Acid Plant Area

DDT and its metabolites were detected in shallow- and intermediate-zone groundwater downgradient of the Acid Plant Area. DDT is not typically observed in groundwater at concentrations greater than 1 μg/L. However, due to cosolvency with chlorobenzene, DDT has been observed in groundwater at concentrations up to 450 μg/L (shallow-zone monitoring well MWA-15r, 30 March 2001). The highest concentrations of DDT were observed slightly upgradient of the highest concentrations of chlorobenzene. DDT was not observed in intermediate-zone groundwater in the Acid Plant Area during the two most recent sampling events (April 2002 and June 2003). Historically, DDT has been observed in deep- and basalt-zone groundwater at concentrations up to 0.43 and 0.022 μg/L, respectively. These concentrations are approximately three and four orders of magnitude less than the DDT concentrations observed in shallow-zone groundwater. DDT was not detected in the groundwater sample collected in June 2003 from monitoring well MWA-13d above the detection limit of 0.08 μg/L.

The RI has bounded groundwater affected by DDT in the shallow and intermediate groundwater zones upgradient and downgradient (Willamette River) of the Acid Plant Area. Additionally, the RI has bounded the northern and southern (cross-gradient) extents of DDT impacts in shallow-zone groundwater, as well as the northern and southern extents of DDT impacts in intermediate-zone groundwater.

In addition to DDT, VOCs (primarily chlorobenzene) were detected in shallow- and intermediate-zone groundwater, primarily downgradient of the Acid Plant Area (e.g., monitoring wells MWA-15r and MWA-2 [shallow zone], and monitoring wells MWA-9i and MWA-17si [intermediate zone]). The maximum observed chlorobenzene concentrations were comparable for these two groundwater zones (260,000 and 140,000 µg/L); however, the lateral extent of chlorobenzene impact is greater in the shallow zone. Chlorobenzene was also detected in the deep- and basalt-zone monitoring wells (MWA-13d and MWA-21b) during the RI. Chlorobenzene concentrations in the deep zone (10.6 µg/L, MWA-13d, 9 June 2003) were approximately two to three orders of magnitude less than concentrations in the shallow zone; concentrations in the basalt zone (0.69 mg/L, MWA-21b, 12 April 2002) were approximately four to five orders of magnitude less than concentrations in the shallow zone. Since chlorobenzene is present as residual DNAPL, these results suggest that the lower-permeability silt layers separating the groundwater zones have impeded significant downward transport of chlorobenzene.

This investigation has bounded groundwater affected by chlorobenzene upgradient and downgradient of the Acid Plant Area. The southern extent of chlorobenzene in the shallow zone and the northern extent of chlorobenzene in the intermediate zone have been well defined. However, further investigation is required to define northern extent of chlorobenzene in the shallow zone and the southern extent of chlorobenzene in the intermediate zone. A work plan for further investigation of the southern extent of chlorobenzene in the intermediate zone was submitted on 5 December 2003 and was approved by ODEQ on 15 January 2004. These investigations will be performed prior to conducting the Baseline Risk Assessment.

Residual DNAPL (chlorobenzene) was observed in the shallow and intermediate groundwater zones downgradient of the Acid Plant Area. A two-phased DNAPL investigation was carried out to further characterize the nature and extent of the observed DNAPL. The investigation concluded that residual DNAPL is generally confined to the lower portion of the shallow zone (i.e., within approximately 6 feet of the silt layer defining the bottom of the shallow zone), with the exception of one detection of residual DNAPL in the intermediate zone directly below the former MPR pond. The investigation also concluded that the DNAPL is distributed as ganglia, and thus is not readily mobile in the subsurface.

The DNAPL is a likely on-going source of dissolved chlorobenzene in groundwater.

9.1.2.2 *Ammonia in Groundwater*

Direct-push boring B-67 was conducted on 2 May 2001, downgradient of the former Ammonia Manufacturing Plant, which was situated approximately where the southern portion of the new caustic tank farm is shown on Figure 2-1. Ammonia was detected in the groundwater sample collected from this boring at a concentration of 1.22 mg/L. In June 2001, ammonia was observed in groundwater samples collected from monitoring wells MWA-5 and MWA-14i at concentrations up to 15 and 2.9 mg/L, respectively. This data was presented to ODEQ in the Quarterly Progress Report prepared by ATOFINA Chemicals, dated July 2001. In a letter to ATOFINA Chemicals, dated 29 August 2001, ODEQ stated "additional characterization of the ammonia impacts to groundwater" was necessary and requested ATOFINA Chemicals propose a strategy for additional evaluation of ammonia in groundwater (ODEQ 2001).

In response to ODEQ's 29 August 2001 letter, ATOFINA Chemicals assembled groundwater quality data from off-site, upgradient shallow- and intermediate-zone groundwater wells from the Rhone-Poulenc AG Company (RPAC) property. The data indicated that ammonia had been observed in off-site monitoring well W-04-S at a concentration up to 34.5 mg/L. Monitoring well W-04-S is located across NW Front Avenue from the Site, upgradient of the former Ammonia Manufacturing Plant and monitoring wells MWA-5 and MWA-14i (Figure 3-10). ATOFINA Chemicals presented this data to ODEQ in a letter dated 25 February 2002. ODEQ responded to this letter in a letter dated 21 March 2002, in which ODEQ agreed that the data from the RPAC monitoring wells indicated that it is likely that ammonia has migrated with groundwater onto ATOFINA Chemicals property (ODEQ 2002b). In that letter, ODEQ also stated that ATOFINA Chemicals was required to perform additional sampling before application of the Contaminated Aquifer Policy (ODEQ 1997).

In response to ODEQ's 21 March 2001 letter, direct-push boring B-119 was advanced upgradient of the former Ammonia Manufacturing Plant on June 2002 (Figure 2-1). The groundwater sample collected from this boring contained ammonia at a concentration of 2.0 mg/L. This data was presented to ODEQ in the October 2002 Quarterly Progress Report.

ATOFINA Chemicals has reviewed conditions A through D of the Contaminated Aquifer Policy and concludes that based on the analytical results for ammonia in the direct-push boring groundwater samples collected upgradient and downgradient of the former Ammonia Manufacturing Plant and analytical results from off-site, upgradient wells screened in the same groundwater bearing zones, the Contaminated Aquifer Policy applies to ammonia at the Site.

9.1.2.3 Chlorate Plant Area

Chromium and hexavalent chromium were detected in shallow- and intermediate-zone groundwater in the vicinity of the Chlorate Plant Area, both in groundwater grab samples collected from direct-push borings and in monitoring well samples. Chromium was detected in the shallow-zone grab sample collected from boring B-80 at a concentration of 110 mg/L (estimated value). Shallow-zone monitoring well MWA-33 was installed adjacent to boring B-80. The groundwater sample collected from MWA-33 in June 2003 contained chromium at a concentration of 0.601 mg/L, approximately two orders of magnitude lower than the concentration measured in the sample collected from the direct-push boring. This result suggests that the concentration of chromium in the groundwater sample collected from boring B-80 may be erroneously high. Samples collected from direct-push borings typically bias high due to high sedimentation and the inability to properly develop and purge the boring.

The highest chromium concentration detected in shallow-zone groundwater during the June 2003 sampling event was 9.79 mg/L (monitoring well MWA-25). Chromium was also detected upgradient of the Chlorate Plant Area in well MWA-23, at a concentration of 0.00117 mg/L (June 2003).

Chromium was detected in intermediate-zone groundwater at concentrations up to 1.15 mg/L (monitoring well MWA-31i) during the most recent groundwater sampling event (June 2003). Chromium was not detected in intermediate-zone well MWA-28i. Well MWA-28i is upgradient of well MWA-31i and adjacent to shallow-zone well MWA-25, which had the highest chromium detection in June 2003. This suggests that dissolved chromium moved downward as it migrated east-southeast from the Chlorate Plant Area. The RI has adequately defined the extent of chromium impacts in groundwater for the purposes of performing a risk assessment and FS.

The RI identified perchlorate in shallow- and intermediate-zone groundwater. Concentrations up to 290 and 200 mg/L were observed in the shallow and intermediate groundwater zones, respectively. Perchlorate impacts in shallow-zone groundwater are more laterally extensive than those in the intermediate zone. The RI has bounded perchlorate in shallow-zone groundwater to the west (upgradient) and east (downgradient, Willamette River). Perchlorate was detected at a very low concentration in shallow-zone monitoring well MWA-29, on the southern edge of the Site (0.110 mg/L, June 2003). Additionally, perchlorate was detected in monitoring well MWA-2 during the most recent (June 2003) groundwater sampling event (1.4 mg/L). Well MWA-2 was the northernmost well sampled for perchlorate. Sampling of the northernmost shallow-zone well (MWA-5) will be performed prior to the performance of the risk assessment. For the purposes of performing a risk assessment and FS, the RI has adequately defined the extent of perchlorate impacts in the shallow and intermediate zones.

Chloride was observed in groundwater at all wells during all sampling events. Chloride is a naturally occurring ion in groundwater. However, elevated chloride concentrations were observed on the downgradient side of the former Salt Pads, where salt was stockpiled and where salt brine was produced for use in manufacturing. Concentrations up to 164,000 and 61,100 mg/L, respectively, were observed in the shallow and intermediate groundwater zones. The elevated chloride concentrations are limited to the area near the eastern edge of the former Salt Pads.

9.1.3 Storm Water

Dissolved DDT, DDD, and DDE were generally not detected in storm water from the Acid Plant Area. Additionally, no dissolved pesticides were detected in the last round of storm water sampling (March 2001). This sampling event took place after the Phase I soil removal IRM had been carried out, which removed shallow DDT-impacted soil and paved areas in and around the Acid Plant Area with asphalt or concrete.

Total DDT and its metabolites were detected in storm water at low μg/L concentrations, which suggests that some pesticide-containing particulate material was present in the storm water samples. Significant reductions in total DDT and metabolite concentrations in storm water were observed after the Phase I IRM was completed; total DDT concentrations were approximately half of what had been previously observed, and DDT metabolite concentrations were approximately an order of magnitude less than previously observed levels.

The low concentrations of DDT and metabolites detected in storm water samples suggest that storm water runoff from the Site is not a significant source of DDT to Willamette River sediments.

9.2 CONCLUSION

The remedial investigation conducted at the ATOFINA Chemicals facility in Portland, Oregon, has adequately defined the nature and extent of COIs in upland soil and groundwater and provides sufficient data for conducting the Baseline Risk Assessment and FS.

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